September 1960

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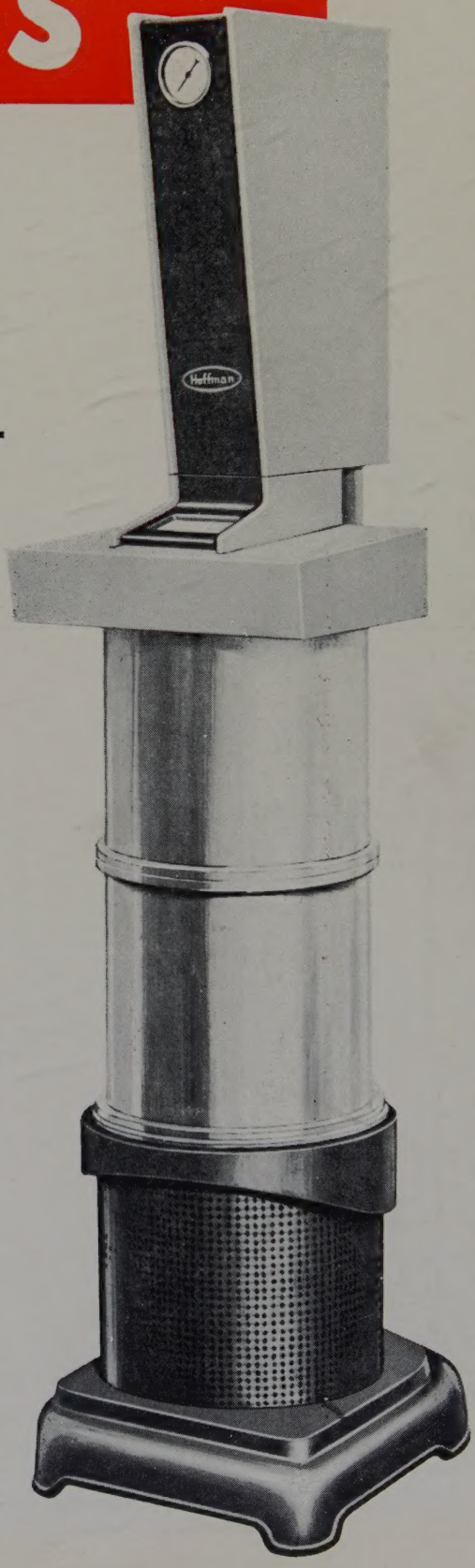
EMICONDUCTOR PRODUCTS

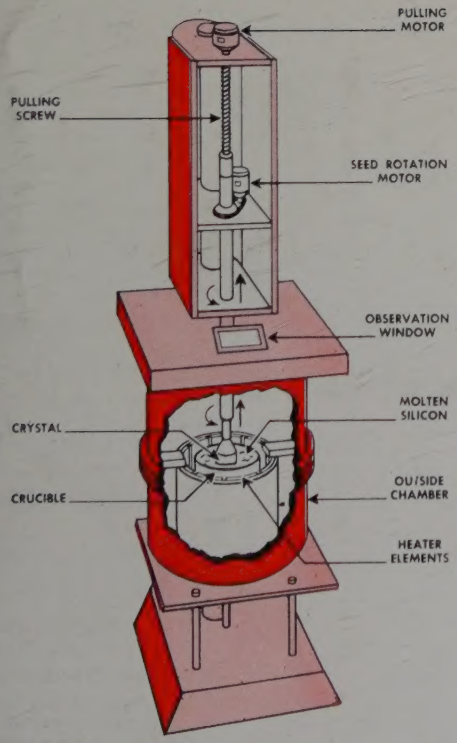
ansistor Switching Analysis

nary-Quinary Decade Counter

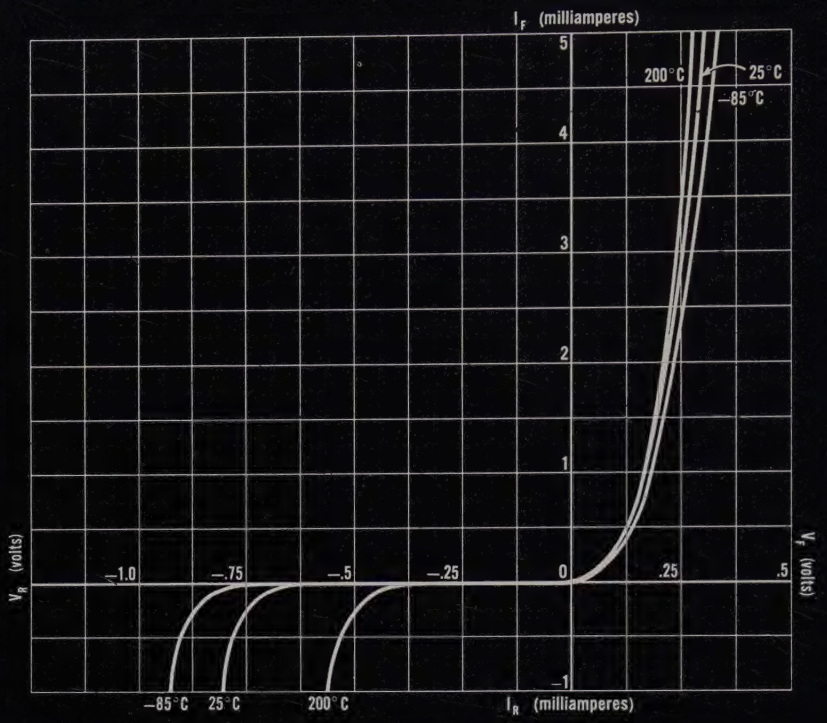
gh Gain Silicon Transistors

ansistorized Pulse Code Repeater



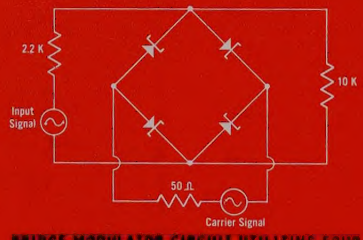


Automatic Programmed Crystal Furnace



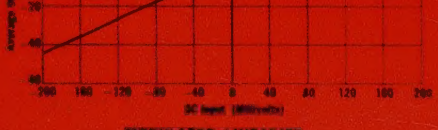
TYPICAL UNI-TUNNEL DIODE CHARACTERISTICS

HOW HOFFMAN UNI-TUNNEL DIODES SIMPLIFY AND IMPROVE MODULATOR CIRCUITRY DESIGN

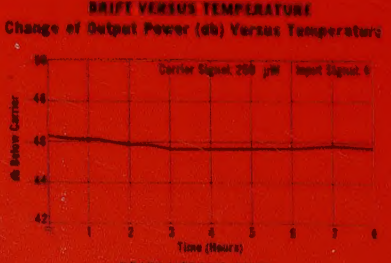


BRIDGE MODULATOR CIRCUIT UTILIZING FOUR HOFFMAN UNI-TUNNEL DIODES

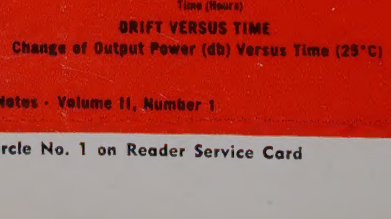
These Graphs Illustrate Typical Operating Characteristics of the Modulator Circuit Above



MODULATOR LINEARITY
Average Output Voltage Versus DC Input Voltage



DRIFT VERSUS TEMPERATURE
Change of Output Power (db) Versus Temperature



DRIFT VERSUS TIME
Change of Output Power (db) Versus Time (25°C)

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- detectors
- choppers
- clampers
- tunnel diode circuitry

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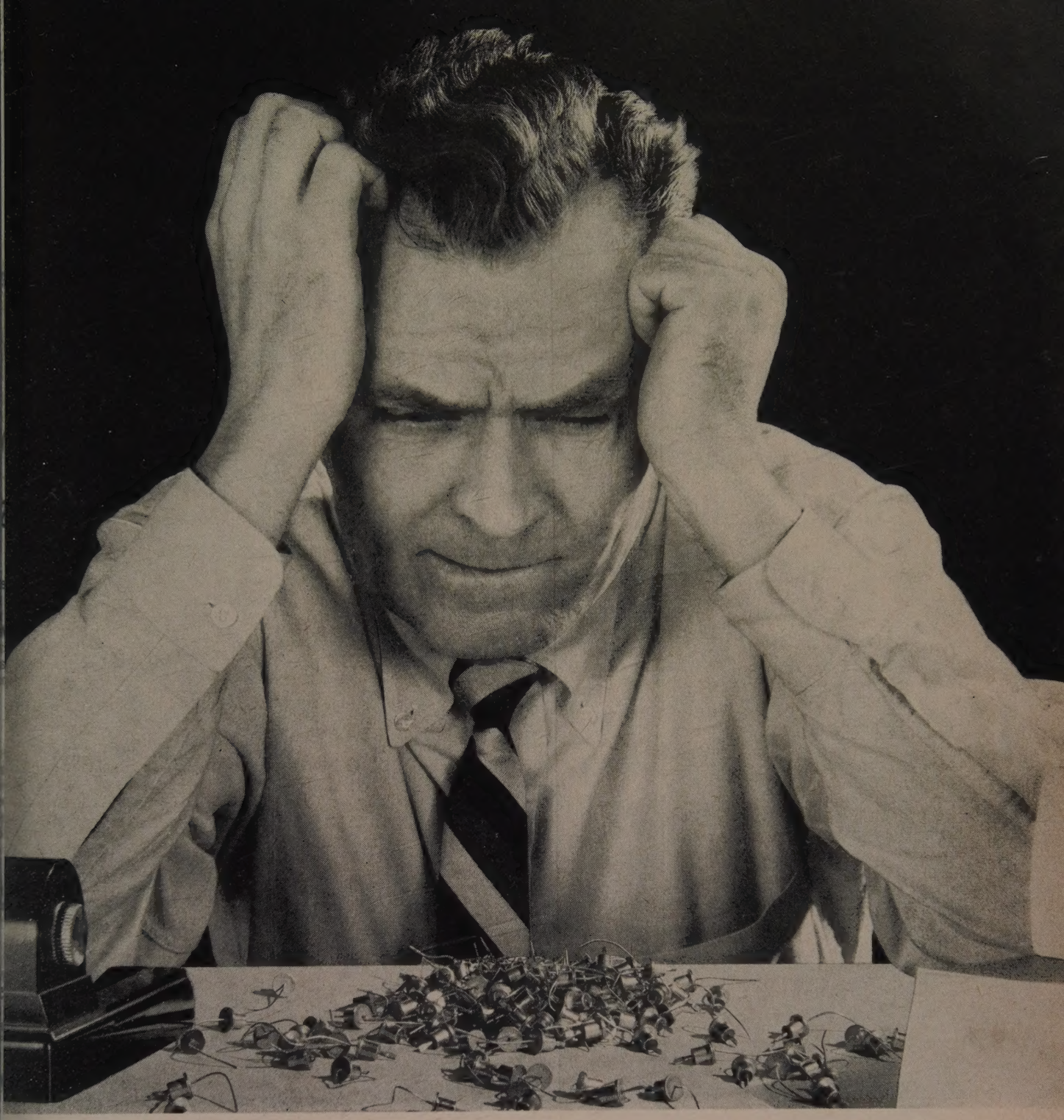

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September 1960 Vol. 3 No.

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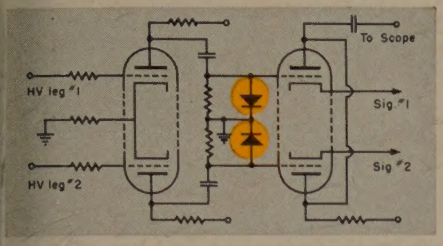
Front Cover

Illustrates a new crystal-growing furnace developed by Hoffm Electronics Corporation. A resistance heating system is used. the bottom of the furnace itself is an inert gas-filled, sealed cha ber. The gas displaces oxygen trapped in the chamber as well that given off by the quartz crucible. This eliminates any suspended contamination. The remainder of the furnace is devot to the heating system and rotating mechanism. The furnace h complete automatic programming.

GENERAL INSTRUMENT SEMICONDUCTOR REPORT

Design Notes...

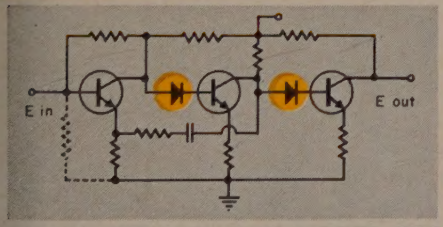


DIODE CLAMPS PREVENT DRIFT IN HIGH SPEED ELECTRONIC SWITCHES The problem of drift in high speed electronic switches has been solved through the use of clamp diodes. This application is especially useful for stabilizing the operation of go, no-go oscilloscopic testing of dynamic parameters in a variety of electronic components.

In the circuit, General Instrument MP-300 silicon diode/rectifiers may be used because of their superior stability and low reverse leakage (only .05 μa @ 25°C).

Changing from vacuum tube to silicon clamp diodes minimizes problems associated with varying contact potentials. Equipment reliability is improved since total thermal dissipation is reduced. Further, equipment does not have to be reset in case of power line failure.

The small physical size of General Instrument diode/rectifiers is important where a large number of switches are to be used in a single piece of equipment.



NOVEL CIRCUIT USES DIODES FOR AUDIO COUPLING There are many benefits to be gained through *diode coupling* of audio amplifiers. The simplified three-stage transistorized audio amplifier shown above uses General Instrument IN645 subminiature silicon diodes.

Since the diodes are forward biased, ac is virtually direct coupled—resulting in a flat frequency response limited only by transistor parameters. Need for large coupling capacitors is eliminated. Virtually lossless ac coupling is obtained. And, temperature stability is improved because of low external base resistance.

Complete schematics of above circuits are available upon request.

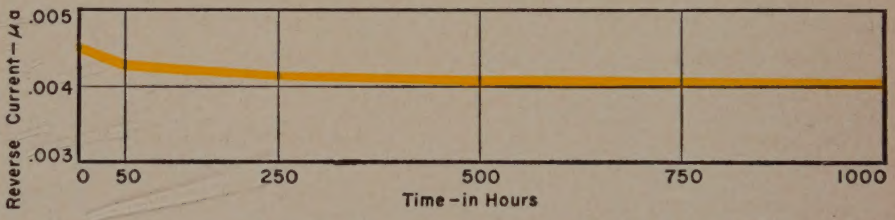
Proved Reliability: ZERO FAILURES after 11,000 hours operation at 150° C!

GI IN 645-IN 649 DIODE/RECTIFIERS AVAILABLE IN PRODUCTION QUANTITIES... EXCEED USAF STANDARDS

General Instrument 1N645 through 1N649 subminiature rectifiers are ideally suited for applications requiring small size and very high reliability. These hermetically sealed glass units are designed to operate over an ambient range from −65° to 150°C . . . pass MIL-E-1/1143 specfications for breakdown voltage . . . offer superior life test performance. This series covers the range of 225 to 600 PIV, with maximum average rectified current of 400 ma @ 25°C. Maximum reverse current @ PIV is only 0.2 μa.

These diode/rectifiers are subjected to 100% environmental testing and dynamic oscilloscopic tests to assure high electrical and mechanical uniformity, surpassing the most stringent military specifications.

■ **LIFE TESTS** indicate outstanding stability of the General Instrument 1N645 series subminiature rectifiers under load. Graph shows results of a 1,000-hour test of 231 units from a normal production run. (Conditions: VRMS 160 V ac; Io 400 ma dc.)



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		25°C	200°C	25°C	200°C	
MP 100	100	400	50	.05	75	1.0
MP 225	225	400	50	.05	75	1.0
MP 300	300	400	40	.05	75	1.0
MP 400	400	400	35	.05	75	1.0
MP 500	500	400	25	.05	75	1.0
MP 600	600	400	20	.05	75	1.0

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CLARE TRANSISTOR

Characteristics at 25°C

	Min. BV_{CBO}	Min. V_{PT}	fαb	Min. h_{FE}	Max. Rated Dissipation
2N398 (PNP)	−105Vdc	−105Vdc	—	20 at I_C=−5mAdc	50mW
CP398 (PNP)	−105Vdc	−105Vdc	1mc typ.	30 at I_C=−5mAdc	150mW
2N1310 (NPN)	+90Vdc	+90Vdc	—	20 at I_C=+5mAdc	120mW
CP98 (PNP)	−65Vdc	−65Vdc	4mc min.	30 at I_C=−30mAdc	150mW

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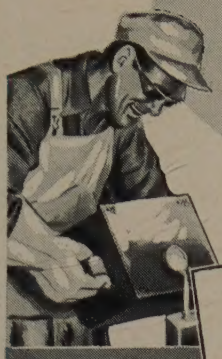

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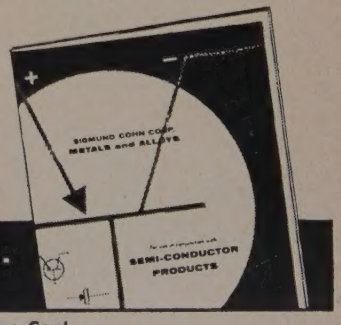

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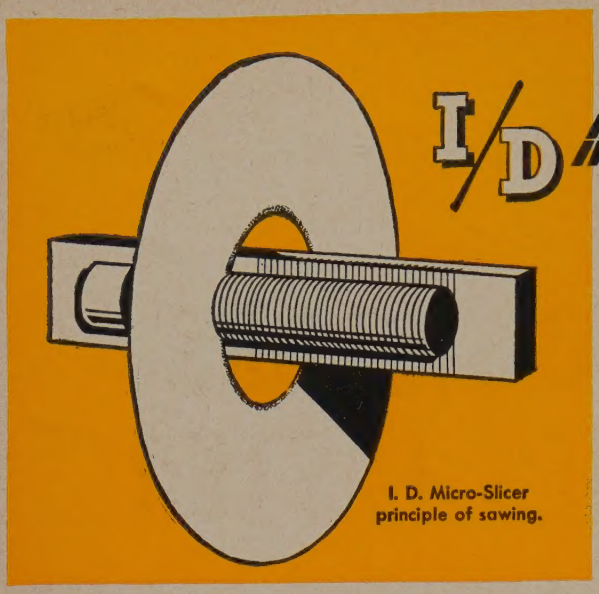

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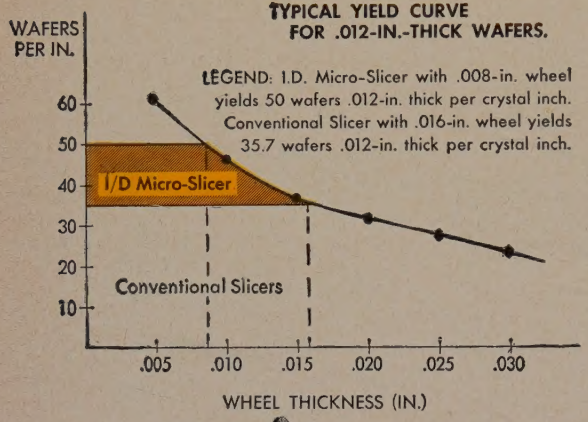
**U.S. Patent 2,713,339. Canadian Patent 551,690.*



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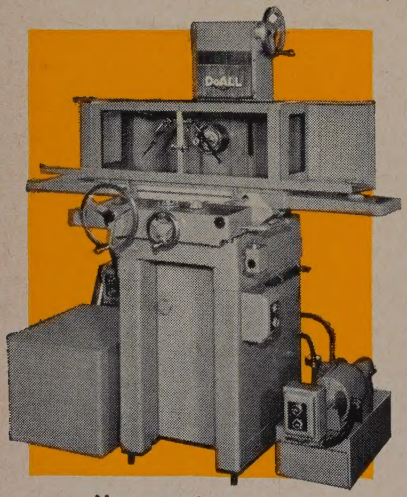

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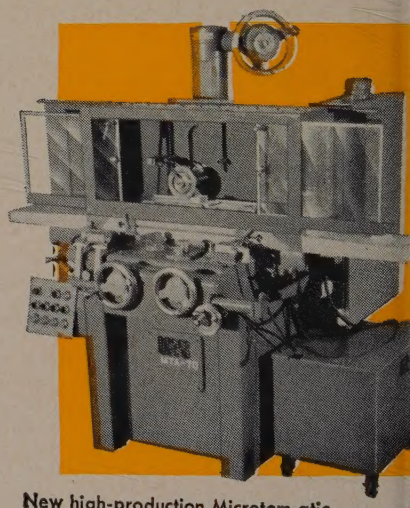

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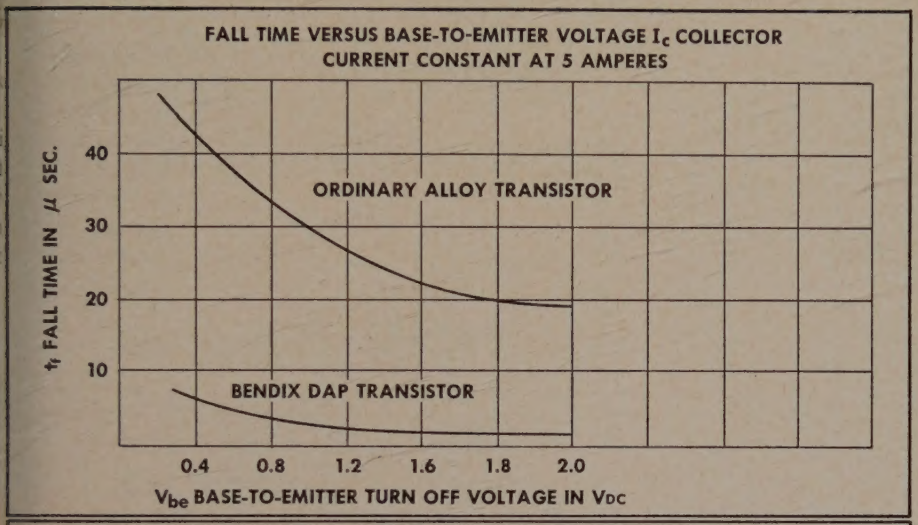

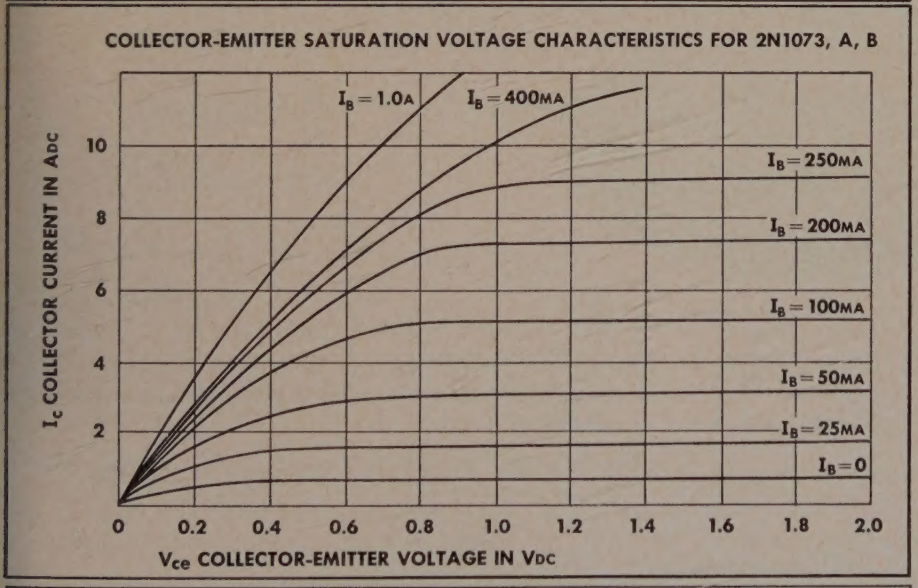

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TYPE NUMBERS	Vce Vdc	Vcb Vdc	Veb Vdc	Ic Adc	Pc W	T Storage °C	Tj °C
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2N1073A	— 80	— 80					
2N1073B	—120	—120					

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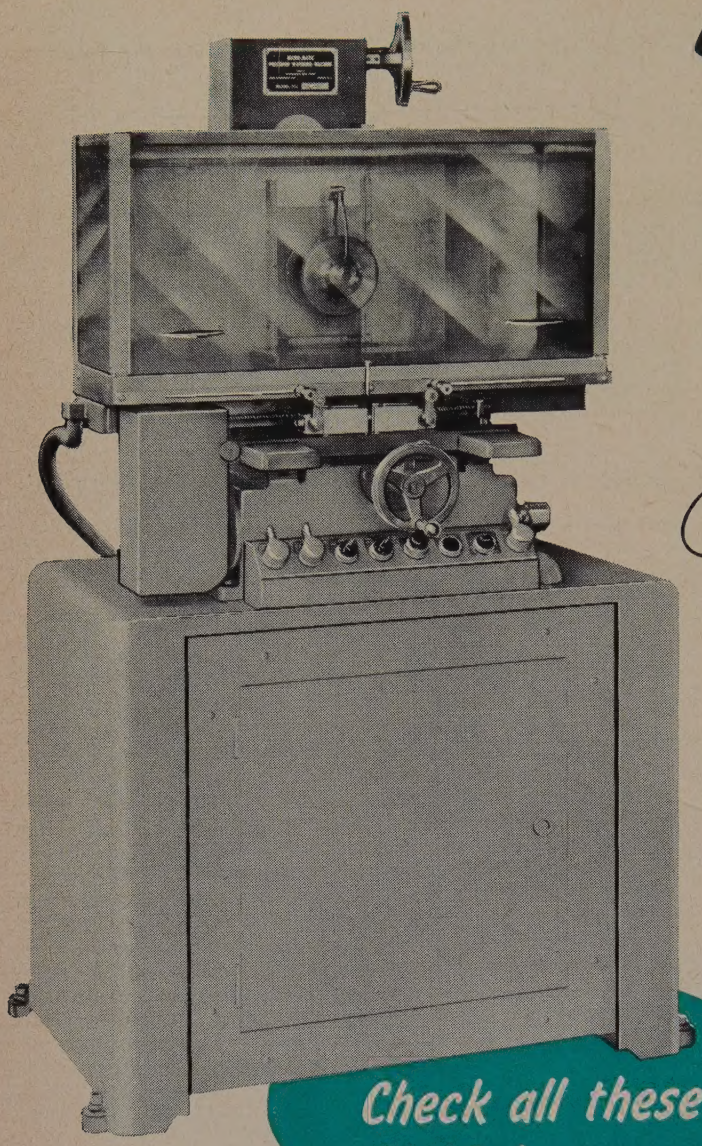

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A Division of Sanford Manufacturing Corp.

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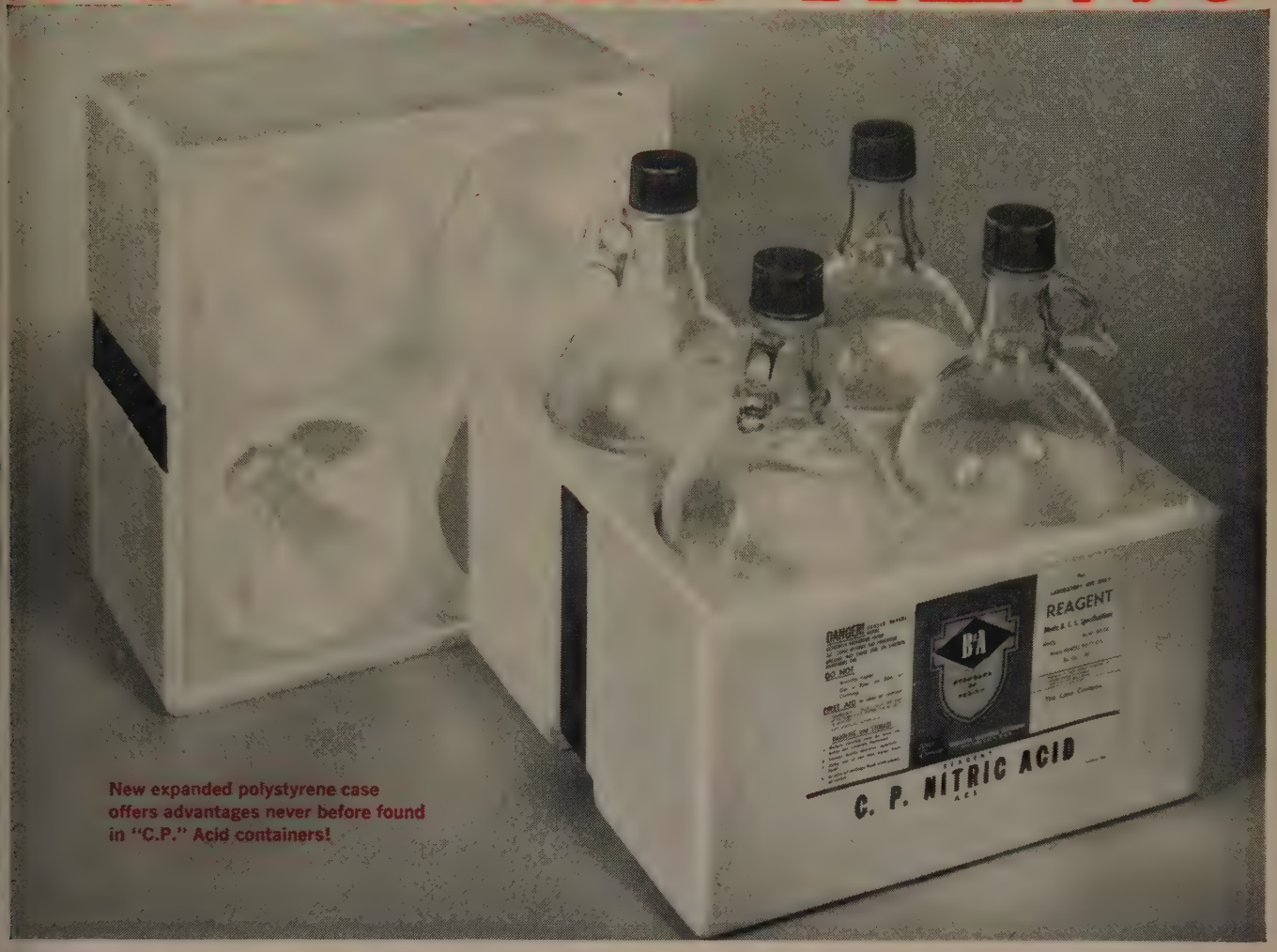
TOTALLY NEW!



Lighter! Stronger! Safer! Exclusive new expanded polystyrene case for B&A® "C. P." Acids!

An exclusive development of General Chemical, this new "one-way" case holds four 5-pint "C.P." acid bottles in contoured pockets formed of shock-resistant low density expanded polystyrene. Here is still another packaging "break-through" from America's leading producer of laboratory and scientific chemicals . . . another example of continuing B&A leadership in reagent packaging.

Smaller! Lighter! The new case is substantially smaller than old-fashioned containers and is far easier to store and handle. Tare weight with empty bottles is less than 11 pounds. This saves you money on freight.

Easier to handle! Convenient finger grips make case easy to lift and carry. Top and bottom specially designed with interlocking feature for safe stacking.

Safer! The new polystyrene case is chemically resistant, and it is weather-resistant, too. Withstands outdoor storage. Bottles are "cradle cushioned," fully protected in form-fitted polystyrene pockets.

Stronger! The new case is far stronger than other "one-way" cases now in use for "C.P." acids. In thorough and extensive testing, it has met the most stringent ICC drop test requirements . . . bottles remained unharmed after 16 separate drops from a 4-foot height!

Order Now! These new units are now ready for shipment from General Chemical's B&A distributing points coast to coast. They have had more than a year of intensive research and testing and are *proved* superior to any other type of "shipper" now available! For further information, phone or write your nearest B&A office.

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Allied Chemical

GENERAL CHEMICAL DIVISION
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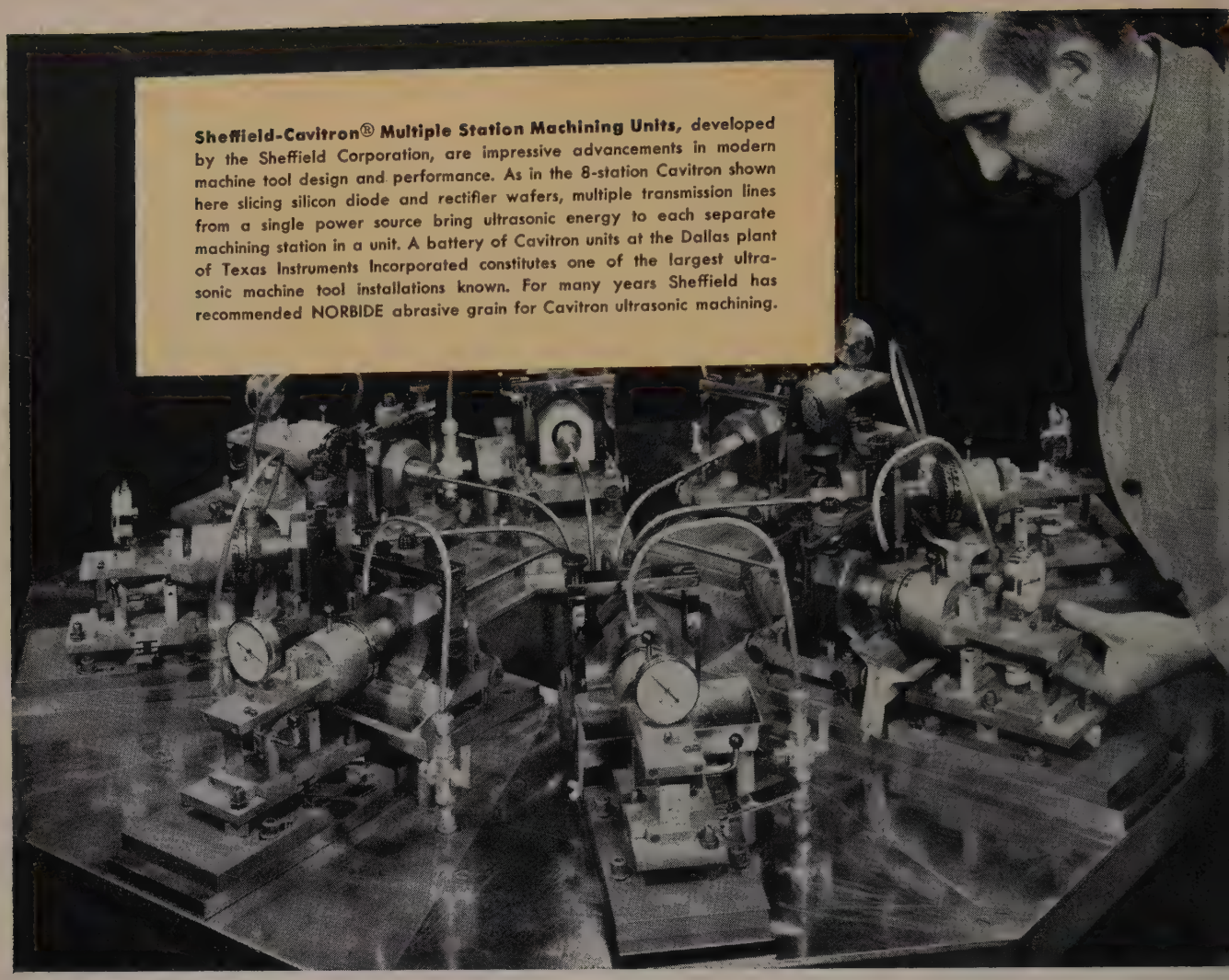

Sheffield-Cavitron® Multiple Station Machining Units, developed by the Sheffield Corporation, are impressive advancements in modern machine tool design and performance. As in the 8-station Cavitron shown here slicing silicon diode and rectifier wafers, multiple transmission lines from a single power source bring ultrasonic energy to each separate machining station in a unit. A battery of Cavitron units at the Dallas plant of Texas Instruments Incorporated constitutes one of the largest ultrasonic machine tool installations known. For many years Sheffield has recommended NORBIDE abrasive grain for Cavitron ultrasonic machining.

FOR ULTRASONIC MACHINING . . .

the best abrasive – NORBIDE Boron Carbide is now even better!*

Keeping pace with the development of ultrasonic machining to bring high precision to more and more applications, NORBIDE boron carbide is preferred as the ideal cutting agent for these rapidly increasing operations.

And now new Norton manufacturing techniques have brought improvements to NORBIDE abrasive . . . which bring even more advantages to ultrasonic machining than ever before!

Always recognized as second only to diamonds in hardness, and as much more suitable than silicon carbide grain, NORBIDE boron carbide grain now has greater freedom from impurities.

This means more effective, longer lasting cutting power in each ounce of NORBIDE boron carbide.

Remember: ultrasonic machining is rapidly spreading its advantages throughout industry — metalworking, electronics, fine glass, laboratory ware, jewelry and many other manufacturing fields. Materials machined include a wide range of metals, ceramics, refractories, etc. Operations include slicing, shaping, slotting, engraving, multi-drilling, etc. In all applications, on all materials, NORBIDE boron carbide is the most dependable abrasive for high precision, product quality and economy.

Your Norton Man can assist yo in obtaining facts about how ultra sonic machining with NORBID abrasive can benefit your produ tion. See your Norton Distribut or write to NORTON COMPAN General Offices, Worcester Mass. Plants and distributo around the world.

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how to split a

SPLIT SECOND

New HUGHES® nanosecond diodes switch 50 times faster than standard germanium diodes. If your circuits require faster response, faster recovery, with greater accuracy, you can solve your problem with Hughes nanosecond diodes.

Hughes nanosecond germanium diodes are designed to make today's circuits better—and tomorrow's possible. They combine the most wanted parameters into one subminiature component. They switch 50 times faster than the usual germanium diode; they have conductances 50% higher; and they have rectification efficiencies greater than 70%. They have higher Q and faster recovery (both forward and reverse), which give your circuits greater accuracy and extremely low transient losses.

These new semiconductors were created especially for high-speed computer logic, high-frequency transistor circuits, extremely fast reference switching, and low-noise, low-level RF modulation and demodulation. If you're working with sophisticated circuitry with exacting requirements, the Hughes Semiconductor sales engineer in your area is a good man to know. Call him.

Or write Hughes Semiconductor Division, Marketing Department, 500 Superior Avenue, Newport Beach, California.

TYPICAL PARAMETER RANGES	
Forward Voltage @ 100mA	.75V to .55V
Reverse Current @ —3V	5μA
Peak Inverse Voltage	1 to 25V
Reverse Recovery**	1.5* to 2.5n sec.
Shunt Capacitance @ zero bias	1.0μμfd
Rectification Efficiency @ 100mc	70%
Q @ zero bias	10
Maximum Power Dissipation	80mW

*1.5n sec. limits PIV to 10 volts

**Switching 10mA to —6 volts and recovering to 2KΩ with a loop resistance of 100Ω. A sampling scope is used for measuring this recovery.

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HUGHES AIRCRAFT COMPANY

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If safety factors are a

MUST in your application . . .

Specify SRC!

An outstanding illustration of SRC quality, reliability and safety is found in its 35 ampere silicon power rectifiers. For example, these hermetically sealed diodes are so conservatively rated that they will withstand **1200 ampere** surges!*

These silicon rectifiers are nominally rated at 35 amperes and are available in a range of 50 to 600 volts. Readily interchangeable with standard existing 35 ampere units, this entire premium rectifier series is now available for immediate delivery at no premium in price!

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When you deal with Semimetals, you receive germanium monocrystals grown to your exact requirement, via either zone-leveling or Czochralski techniques. You specify the resistivity, type, and dislocation density; we produce and control the material to extremely tight tolerances. Standard material for prompt delivery in (111) orientation in either 2-5,000/cm² or 6-12,000/cm² dislocation ranges. Limited quantities can be ordered of other orientations as well as lower etch pit densities.

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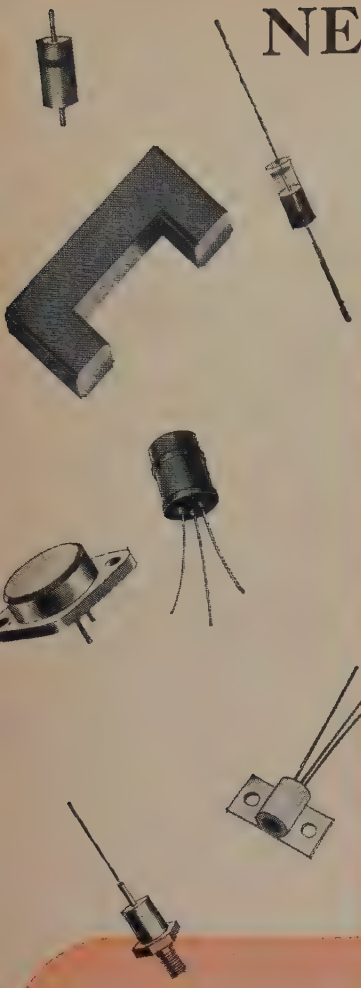

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Calcium Chloride
Calcium Fluoride
Calcium Nitrate
Calcium Phosphate
Carbon Tetrachloride
Cobalt Carbonate
Cobalt Oxide
Cobalt Nitrate
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Hydrochloric Acid
Hydrofluoric Acid
Hydrogen Peroxide, 30% and 3% Solution
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Lithium Nitrate
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Methanol
Nickel Carbonate
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Nickel Oxide, Green
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Nickelous Nitrate
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Potassium Dichromate
Potassium Hydroxide
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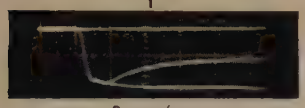
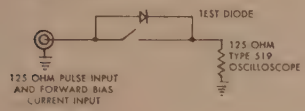


2 nsec/cm

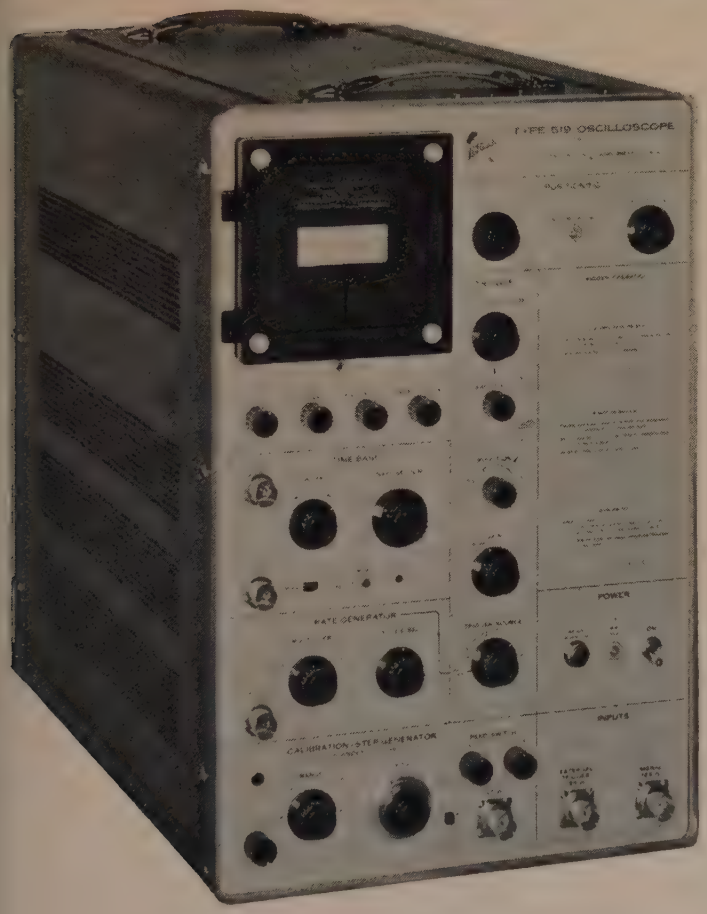
Switching and storage times in fast transistors and diodes can be measured using the outstanding characteristics of the Type 519. In this typical diode-recovery-time waveform, the upper trace is +45 ma reference, the middle trace shows the diode turn-off, and the lower trace shows the diode shorted.

5 nsec/cm

The Type 519 Oscilloscope is an invaluable tool for testing active or passive wideband circuits. In this wideband amplifier waveform little or no correction is necessary for the inherent risetime of the oscilloscope.



The NEW TEKTRONIX KMC OSCILLOSCOPE



Type 519
DC to over 1000 Megacycles
24-kv Accelerating Potential

The new Tektronix Type 519 Oscilloscope is a calibrated high-speed laboratory instrument designed for observation, measurement, and photographic recording of fractional nanosecond risetimes. A 2 x 6 cm viewing area coupled with 24-kv accelerating potential affords bright displays with excellent definition.

Performance features include: passband from dc to beyond 1000 mc, risetime less than 0.35 nsec, sensitivity of 10 v/cm, linear sweeps to 2 nsec/cm, sweep delay to 35 nsec, and a sensitive wideband triggering system. All features are fully compatible with the signal bandwidth capabilities of the instrument. The single unit houses a fixed signal delay line, a convenient sweep-delay control, a pulse-rate generator, a standard amplitude and waveform generator, and electronically-regulated power and high voltage supplies. Only two connections are necessary for normal operation—signal input and power cord.

Combining simple operation with laboratory precision and reliability, the Tektronix Type 519 Oscilloscope is ideally suited to single-shot or random nuclear events. In addition, the extreme bandwidth of the Type 519 permits application to general measurements where oscilloscope risetime must be much faster than signal risetime.

PRICE, Type 519 . . . . . **$3800**
f.o.b. factory

Please call your Tektronix Field Engineer for complete specifications and a demonstration of the Type 519 in your own applications.

CAREER OPPORTUNITIES now exist at Tektronix in the following fields: Instrument design, Circuit design and engineering, Cathode ray tubes, Electron physics, Solid state and semi-conductor devices. For information write to Irving Smith, Personnel Director.

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In Europe please write Tektronix Inc., Victoria Ave., St. Sampsons, Guernsey C.I., for the address of the Tektronix Representative in your country.

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TO: DEVICE DEVELOPMENT ENGINEERS

FROM: TEXAS INSTRUMENTS SEMICONDUCTOR-COMPONENTS DIVISION

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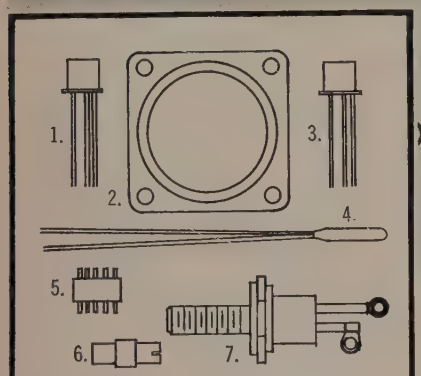
3. Relaxed Living in Modern Dallas, Texas.



Pictured in actual size above are a few of the devices already pioneered by TI engineers: 1. P-N-P Diffused-Base Mesa Germanium Transistor, 2. N-P-N Diffused Junction Silicon Power Transistor, 3. Gallium Arsenide Tunnel Diode, 4. Diffused Photo Duodiode, 5. *Solid Circuit** Semiconductor Network, 6. Diffused Gallium Arsenide Mesa Varactor Diode, 7. Diffused Silicon Controlled Rectifier.

Texas Instruments offers solid state device development engineers the opportunity to pioneer in the application of unique phenomena in semiconductor materials to create specialized components. Studies involve high-speed, high-frequency germanium mesa transistors; tunnel diodes; computer devices; silicon transistors. *Requirements for these key posts:* degree in Electrical Engineering, Physical Chemistry or Physics and experience in semiconductor or related development areas.

INTERVIEWS are scheduled for your area. If the opportunity and challenge of device development at TI intrigues you, please send a confidential summary of your background and your interests to C. A. Besio, Dept. 134.

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Plus or Minus 1° Centigrade . . .

That's the temperature uniformity a user reports he has attained in a Hevi-Duty Tube Furnace engaged in silicon wafer production

Temperature uniformity is tough to achieve. Yet, a Hevi-Duty user reports that his 22-inch-long, 2-inch I. D. furnace has only a ±1°C. temperature variance over 10 inches of furnace length at 1275°C.

Temperature uniformity — so important to producers of semi-conductor products — has been important to Hevi-Duty for years. Attention to this factor has paid off. It has made Hevi-Duty the respected furnace name in the semiconductor industry.

Whenever critical temperatures must be met, you'll find Hevi-Duty equipment. For years, the largest semiconductor manufacturers have used Hevi-Duty furnaces and ovens for zone refining, crystal growth, alloying, lead attachment, surface treatment and encapsulating.

Your Hevi-Duty sales engineer will show you how these proven furnaces and ovens can meet your needs, or write for Bulletin 459.

HEVI-DUTY

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BPC

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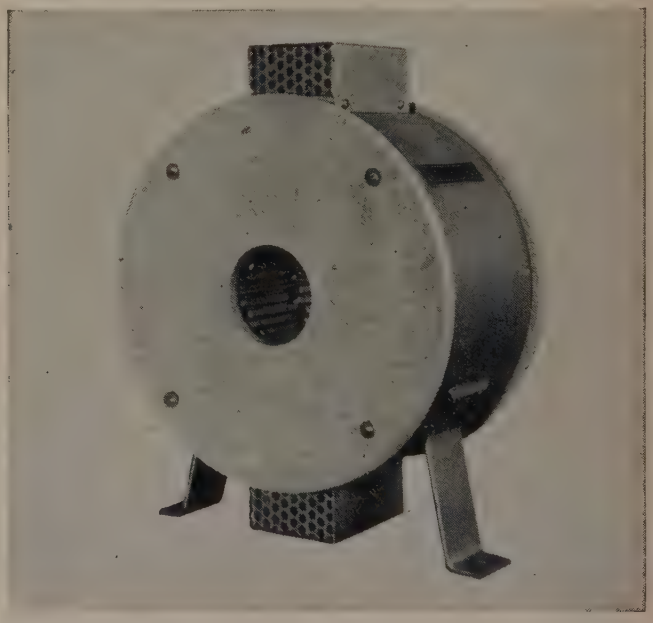
Hevi-Duty Electric Company, Milwaukee 1, Wis.

This special Hevi-Duty furnace assembly is designed for alloying transistors. An automatic saturable reactor temperature control system is built into the base. A preheat furnace operates at temperatures to 2200°F while the two-zone high-heat furnace operates at temperaturs to 2600°F.

Zone refining is accomplished in this special tube furnace with a 3-inch I. D., 4-inch-long heating chamber. The furnace operates at temperatures to 2200°F and can be easily adapted to move along a track for either crystal growth or zone refining.



These two furnaces are being used successfully for the diffusion of silicon wafers. Boats are preheated in the small furnace to the right and then placed in the three-zone high-heat furnace. The cabinet contains saturable reactor controls that automatically maintain correct temperatures in each furnace.

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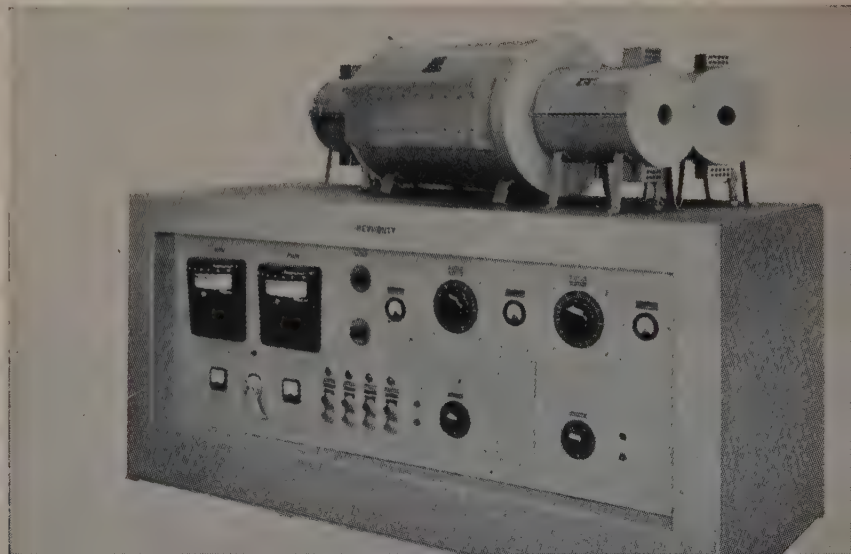
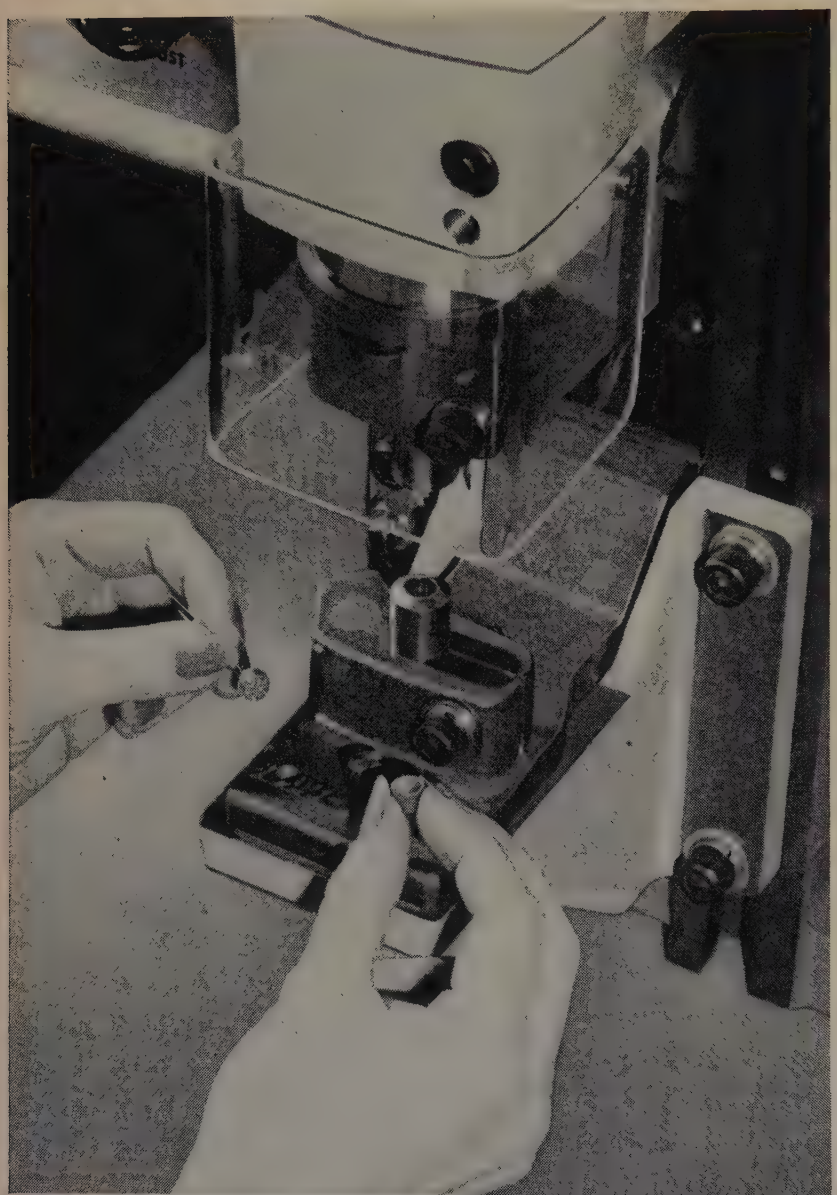


FOR PRECISION WELDING OF TRANSISTORS AND COMPONENTS



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Newest development in precision welding of miniature parts.

The "M" head—Raytheon's completely new precision welding device—assures consistent welding performance even when joining miniature parts. The secret is the advanced design that achieves relatively low welding currents and electrode pressures.

The new head has extremely fast action and a new low-impact anti-hammer arrangement that extends electrode life many times. It has an air chamber that provides for a deflection of less than .0003 inch under full pressure.

The "M" head—thoroughly tested in transistor production—can be mounted horizontally or vertically and is adaptable to dial feed or in-line feed for automated production.

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- Can be used with any welder
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New major producer of semiconductor-grad SILICON...

...announces two intermetallic compounds now in production

Gallium arsenide and indium arsenide, III-V intermetallic compounds n available from Monsanto, promise to open new vistas in electronic engineer —are under active investigation for tunnel diodes and Hall effect devices su as watt transducers, phase detectors, negative resistance amplifiers, ana multipliers, gyrators and isolators, modulators and demodulators.

Monsanto researchers, with a firm base in the commercial production of se conductor-grade silicon, are developing a number of intriguing materials electronics application. Two more examples: gallium phosphide and indiu phosphide are now in advanced stages of research.

If you are planning to invest heavily in extensive product engineering or search and development efforts, be sure you investigate Monsanto's new se conductor-grade silicon and intermetallic compounds. You are invited to ta advantage of Monsanto's exploration and experience in these fields. Write or call: Monsanto Chemical Company, Inorganic Chemicals Division, Dept. S-2, St. Louis 66, Missouri.

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INDIUM ARSENID

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With our millions-of-parts-per-day facilities we specialize in meeting tight specs and stringent production schedules. Parts produced from any of our 4-slide, press, small parts and eyelet equipment must all pass the exacting quality control requirements established for the semiconductor industry and at prices aimed at helping you hold down cost.

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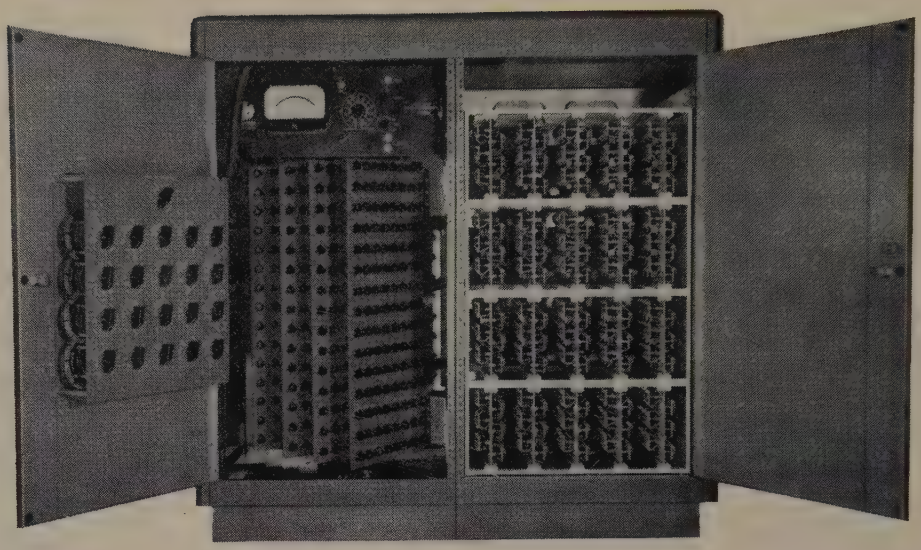
LIFE TEST SYSTEMS

by *Aerotronic*



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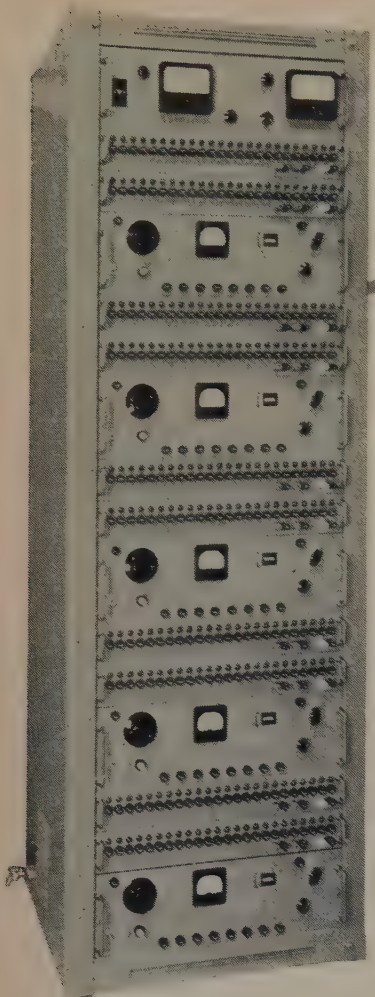

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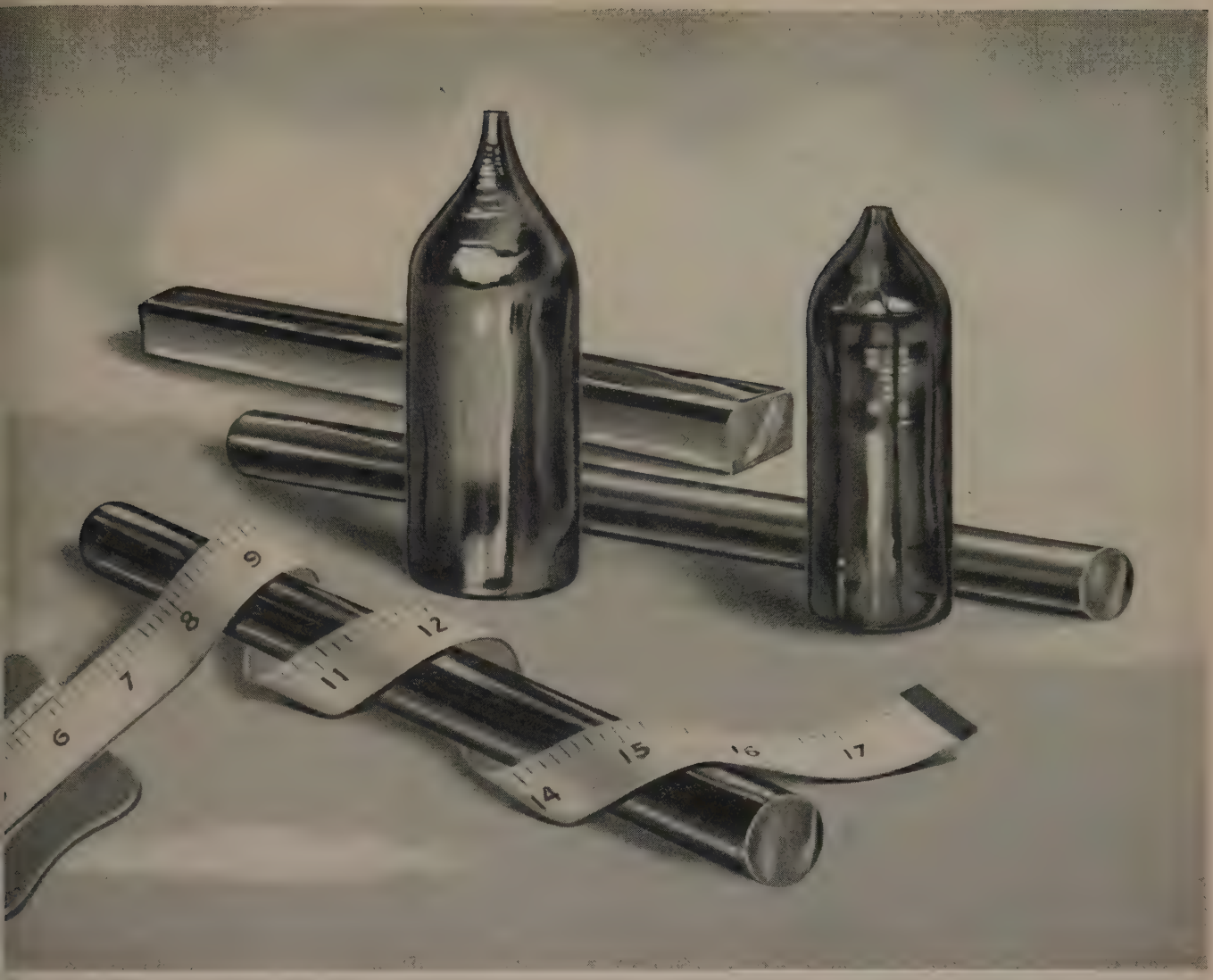
(Continued on page 77)



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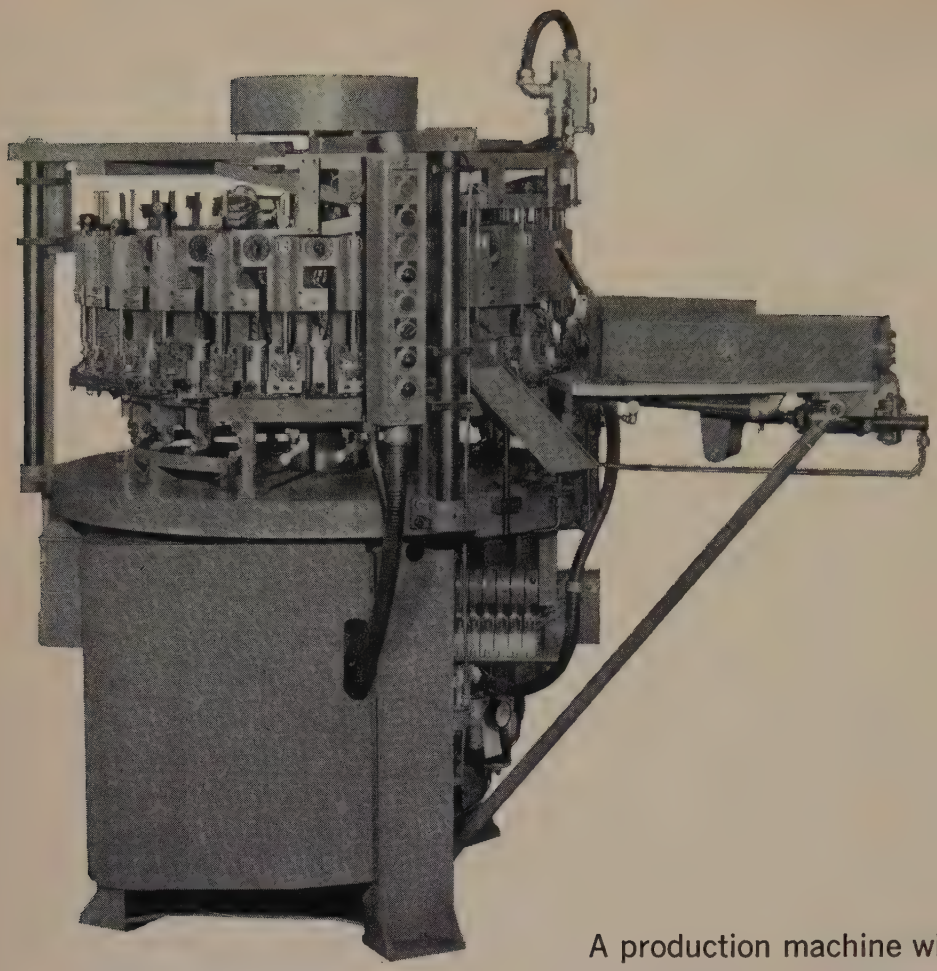

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Editorial . . .

Progress in Tunnel Diodes

Although only recently added to our stock of solid state devices, the tunnel diode already has moved from the laboratory to the production stage. Germanium and silicon diodes are available with high figure of merit and high cutoff frequency, low noise and good thermal stability. The properties of intermetallic compounds, and, in particular, those of gallium arsenide appear also very promising for application to tunnel diodes.

In general, the intermetallic compounds have low minority carrier lifetime and for this reason they are not well suited for the construction of transistors. On the other hand, in the case of tunnel diodes, the majority carrier effects are of predominant importance; gallium arsenide presents high mobility, low effective mass, and in addition has rather low dielectric constant and large energy gap (about 1.35-1.45 ev).

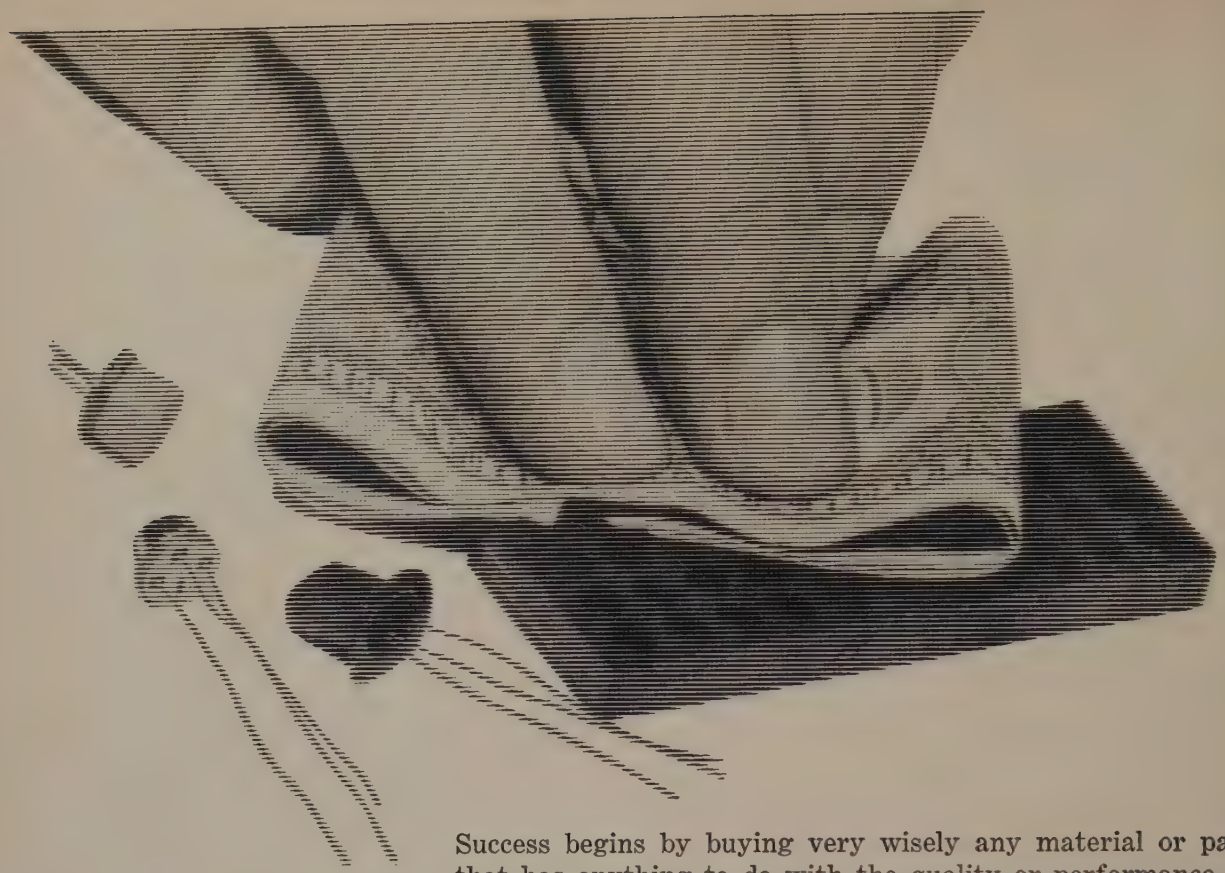
Tunnel diodes with large peak currents and current densities ranging to 10,000 amp/cm^2 have been built. Peak to valley current ratios of 10:1 and up to 60:1 have been obtained, with junction capacitance as low as 0.2 μμF/ma and figure of merit up to 5×10^{10} sec^{-1} (N. Holonyak and I. A. Lesk-*Proc. IRE August '60,1405*).

Crystals of *p*-type may be obtained with cadmium or zinc as doping agents, with doping concentrations of the order of 2×10^{19}/cm^3 and 2×10^{20}/cm^3 respectively; on the other hand crystals of *n*-type are obtained with sulphur, germanium or tellurium as doping agents. Using the familiar alloy technique, tunnel diodes with voltage swings of the order of one volt, series resistance of the order of 2 ohms and frequency of oscillation up to 4.4 kmc have been obtained. The upper limit of the frequency of oscillation seems to be 10 kmc. These diodes are well suited for logic circuitry particularly in combination with germanium diodes, which have low forward voltage step, as steering units. In addition, multivalued functions in both current and voltage may be obtained, by building GaAs and Ge tunnel diodes together, with the latter having lower peak current and larger valley current than the former. Such units may open new possibilities in logic operations, provided they can be built with sufficient reliability.

Other characteristics of importance of tunnel diodes are the thermal stability, the noise figure, the performance under gamma rays and neutron radiation. In general, it seems that materials with lower energy gap have also lower noise figure, but on the other hand, they have larger dependence upon ambient temperature variations. Quantitative information about the noise figure is not well known, and much of the theory has received only a qualitative verification. The thermal behavior of GaAs tunnel diodes is not dissimilar from that of germanium units. In particular, the valley current is found to increase monotonically from 77° K to 500° K, while the peak current has a peak around room temperature. The range of possible utilization of these diodes extends well beyond 500° K.

Finally, the tunnel diodes in general possess very limited sensitivity to gamma and light radiations, and operate satisfactorily in ambients of high nuclear radiation intensity. Fast neutron bombardment produces permanent changes resulting in increases of the valley current and decrease of the voltage swing, in the same way as heating. However, while germanium and silicon tunnel diodes are inoperable under fast neutron doses of 10^{17} nvt, gallium arsenide units still possess appreciable negative resistance characteristic. The latter behavior is particularly important from the point of view of military applications.

Samuel L. Marshall



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A Transistorized Pulse Code Repeater

GORDON R. PARTRIDGE, Ph.D.*

A pulse amplifier, or repeater, for regenerating a train of pulses in a *PCM* cable system is described. The repeater operates at 1152 *kc*, uses about 400 milliwatts of power, and has 26 transistors. The repeater amplifies traffic in each direction in a 24 channel system, and includes fault locating facilities and a loading coil for a voice frequency order wire. Satisfactory operation is obtained over a temperature range from —55 to + 65 degrees Centigrade. This article deals in particular with problems found in the preamplifier and retiming portions of the repeaters, but includes short descrpitions of the output amplifiers and fault locating system.

TWO METHODS ARE AVAILABLE for the simultaneous transmission of several telephone conversations on the same radio beam or cable. These are frequency division multiplex (*FDM*) in which different conversations are assigned different portions of the electromagnetic spectrum, and pulse time modulation (*PTM*) in which different conversations are sampled at intervals and the samples interleaved in time for transmission. Among the methods of pulse time multiplex are pulse position modulation (*PPM*), pulse width modulation (*PWM*), pulse amplitude modulation (*PAM*), and pulse code modulation (*PCM*). This last method is perhaps the most elegant of all, and the most complicated in terms of the necessary terminal equipment. The advantages procured by the increased complexity are a relatively high immunity to noise and, of special importance in some applications, the possibility of encrypting the signals for greater privacy by means other than the usual "scrambler." Under many circumstances, *PCM* systems will be less expensive and more reliable than other multiplex methods.

*Communications Department, Equipment Division, Raytheon Company, Waltham, Massachusetts.

This article describes an amplifier or "repeater" used for the transmission of *PCM* on cable. The repeater is one component of a complete communications system developed for the transmission of 24 simultaneous telephone conversations on military spiral-four cable.

Introduction To The Repeater

Each repeater consists of two amplifier assemblies, plus one power supply, one loading coil, and one fault locator, as shown in *Fig. 1*. Pulses enter the repeater through an input transformer and pass into the preamplifier. Here they are shaped and amplified sufficiently to operate the timing and gating assembly. After being retimed, the pulses continue to the output circuitry where their widths are standardized and they receive sufficient power gain to continue one mile down the cable to the next repeater. The output pulses are approximately 3 volts in amplitude and 0.44 microseconds wide. After propagation over one mile of cable, the amplitude is reduced by about 40 *db*, accompanied by serious degradation in the pulse shape because of the rapid increase in cable attenuation with frequency. The attenuation of one mile of spiral-four cable as a function of frequency is shown in *Fig. 2*. The characteristic impedance at the 1152 *kc* frequency is about 120 ohms.

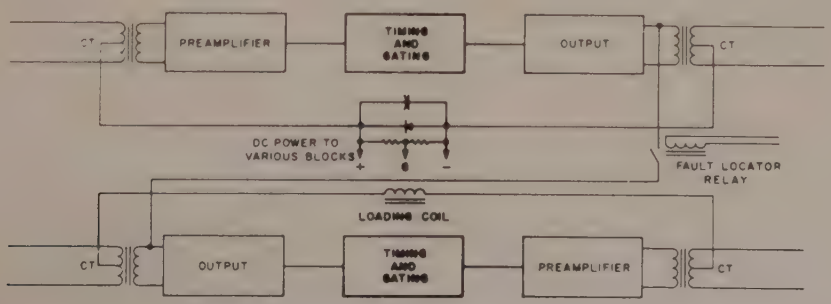


Fig. 1—Block diagram of repeater.

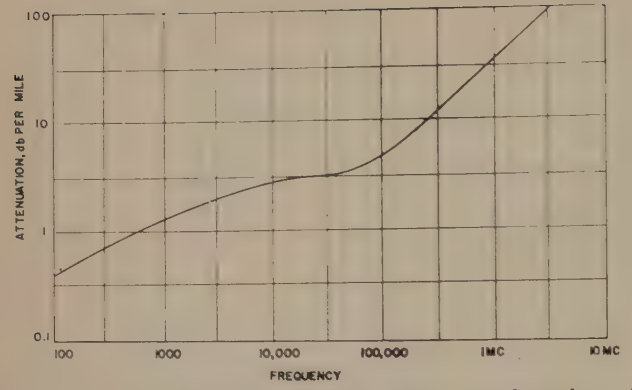


Fig. 2—Attenuation of spiral-four cable as a function of frequency.

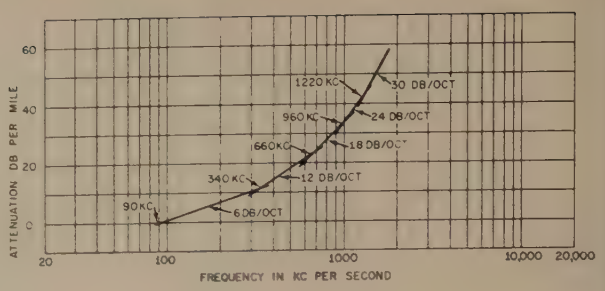


Fig. 3—Straight-line approximation for high-frequency portion of the attenuation curve of Fig. 2.

Power for the repeaters is obtained from direct current traveling from left to right along the cable in the upper left-hand corner of *Fig. 1*, passing through a Zener diode, and leaving the repeater along the cable at the upper right-hand corner. The return path for direct current is in the right-to-left direction across the bottom of *Fig. 1*. The loading coil for a voice-frequency order wire is in series with this path. Each repeater takes 67 milliamperes of current with a drop of 6 volts, or about 400 milliwatts of power.

The function of the fault locator relay is to loop back pulses at a defective repeater. If one of the two output amplifiers should cease delivering pulses for any reason, a sensing circuit notes this fact and closes the relay contacts. The output pulses from the good amplifier are thus returned to the terminal from which they originated. The operator, upon receiving complaints that people at his terminal can talk only to themselves, substitutes a special test pattern for the regular *PCM* traffic. This pattern consists of a sequence . . . 1010101110101010 . . . The terminal equipment determines how long it takes the suddenly inserted group of three "1's" to make the round trip to the faulted repeater and indicates the position of the trouble on a front-panel meter calibrated in miles.

Repeater Circuitry

The remainder of this article deals with the repeater circuits specifically involved in pulse amplification and timing.

Preamplifier Design

It would appear at first glance that the way to recover the pulse pattern is to design an equalizer that has a transfer function exactly opposite to that of the cable. This is essentially true, but special problems associated with the spiral-four cable make it impossible to follow this course exactly. One characteristic of the cable is that, although the identity of a given pair of wires is preserved through a reel of cable, the identity of the two wires in a pair is not. The consequence of this is that, if an equalizer were designed to counteract exactly the attenuation in the cable, the pulses might be either of positive or negative polarity at the output of the equalizer. The amplifier circuits following the equalizer would then have to be responsive to either positive or negative pulses. It is possible to construct such amplifiers, and some were tried out during early experiments in the repeater design. However, it became apparent that a better approach from the standpoint of useful equipment was to differentiate the pulses, so that roughly speaking the preamplifier produces one cycle of an 1152 *kc* sine wave for each "1" in the transmitted code. The negative half of this sine wave operates subsequent circuits, and the only effect of a phase reversal in the cable is to delay the generation of the output pulses by 0.434 microsecond.

The effect of differentiation is to reduce the low frequency response of the preamplifier at a rate of 6 *db* per octave. However, in the vicinity of the baud frequency, a goodly amount of gain and an approximately "flat" frequency response are needed. *Fig. 3* is an enlargement of part of *Fig. 2*, representing the attenuation from 6 *db* per octave to 30 *db* per octave. Break points and slopes are indicated on the curve. The design problem is the placement of zeros in the preamplifier transfer characteristic to cancel the poles

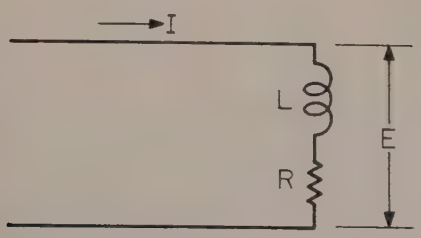


Fig. 4—A zero-producing collector load.

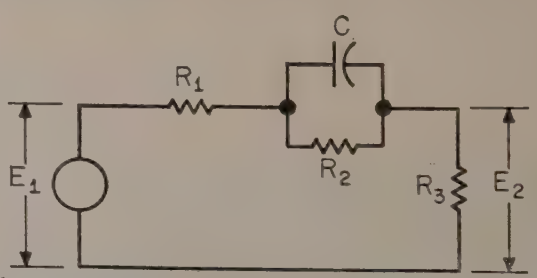


Fig. 5—An interstage network producing a pole and a zero.

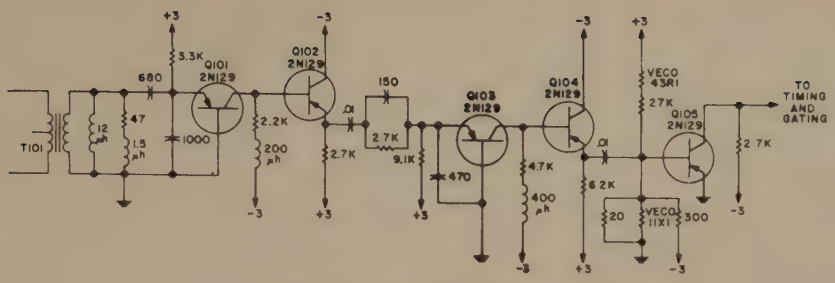


Fig. 6—Complete preamplifier circuit.

represented by the break points in *Fig 3*. The task is somewhat simplified by the fact that gain as well as transfer function shaping is required. Therefore, frequency-controlling elements can be isolated from one another by amplifiers, making it possible to synthesize the transfer function one zero at a time.

Two types of zero-producing configurations were used. One consists of an *RL* collector load, as shown in *Fig. 4*. The radian frequency of a zero in this configuration is

$$s = -R/L$$

Fig. 5 shows an interstage coupling network that produces both a zero and a pole. However, the zero always lies at a lower frequency than the pole, and the pole can be put as far away as desired. The frequency of the zero is

$$s = -1/R_2C$$

and the pole lies at

$$s = -\frac{R_1 + R_2 + R_3}{(R_1 + R_3)\ R_2C}$$

It was decided arbitrarily to use this network to produce a zero at 340 *kc*. The pole was consigned to 10 *mc* where it would presumably do no harm. A value of 150 micromicrofarads was picked for *C*, which led to 3140 ohms for R_2 and 110 ohms for $R_1 + R_3$. The low value of the sum suggested driving this network from a grounded collector stage and loading it with a grounded base stage.

The *RL* loads of the type in *Fig. 4* were used to insert zeros at higher frequencies. The final preamplifier design is shown in *Fig 6*. Zeros are produced by the interstage coupling network between *Q102* and *Q103*, and by the *RL* series loads in the collector circuits of *Q101* and *Q103*. The 12 microhenry inductor shunted across the secondary of the input transformer serves to differentiate the incoming signal train.

It is seen in *Fig. 3* that there are six break points in the straight-line approximation to the cable characteristic. *Fig. 6* does not include that many zero-forming elements. However, it must be remembered that the requirement of the preamplifier is not to restore the incoming signal to its original shape, but rather to produce a positive and a negative pip for each transmitted pulse. The preamplifier as shown is sufficient to do this, and carrying the design farther would be wasteful. It must be conceded that some experimental adjustment of values was necessary. For example, the resistor between *Q102* and *Q103* corresponding to R_2 in *Fig. 5* ended up as 2700 ohms.

The output of transistor *Q104* closely resembles one cycle of a sine wave for each incoming pulse. Transistor *Q105* is driven by the negative halves of these sine waves, and produces positive pulses to drive the timing and gating assemblies.

Timing And Gating

One of the most important considerations in a *PCM* repeater is that of retiming the pulses.* A certain amount of crosstalk occurs from pulse to pulse because exponentially-decaying "tails" are left by pulses passing through high-pass networks. This is illustrated in *Fig. 7*, which shows two pulses in a row. If pulse "1" had not existed, pulse "2" would have followed the dotted path; because pulse "1" did exist, pulse "2" followed the solid path. Suppose that a sampling or triggering circuit of some sort is actuated at the 0.5 amplitude level. It is seen that there is a small time deviation Δt between the two possible moments when pulse "2" can cross this level. This causes a time jitter to be introduced into the pulse train. *Fig. 7* is somewhat simplified in that the exponential paths are

* A set of four articles on retiming in repeaters appeared in the November, 1958, issue of the *Bell System Technical Journal*: O. E. DeLange, "The Timing of High-Speed Regenerative Repeaters," p. 1487; W. R. Bennett, "Statistics of Regenerative Digital Transmission," p. 1501; and H. E. Rowe, "Timing in a Long Chain of Regenerative Binary Repeaters," p. 1543.

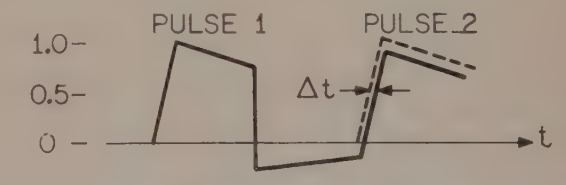


Fig. 7—The effect upon one pulse of another immediately preceding it.

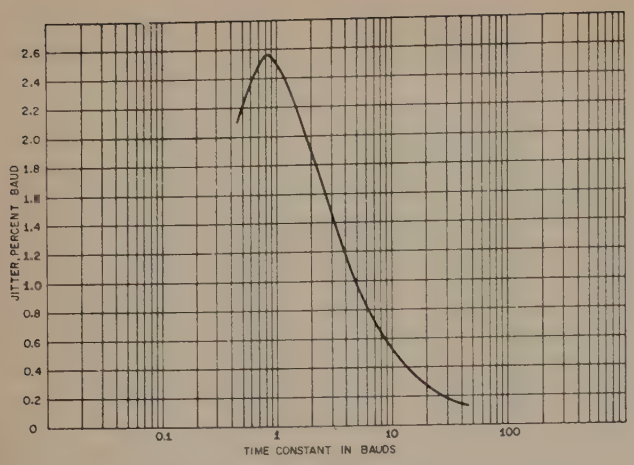


Fig. 8—Jitter in a simple pulse train as a function of the time constant in a high-pass coupling circuit.

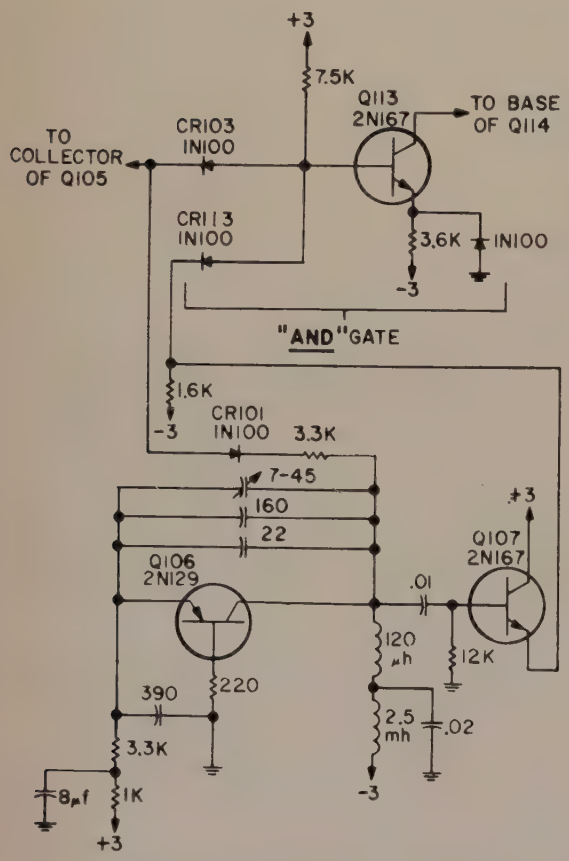


Fig. 9—Timing and gating assembly.

represented by straight lines, and the fall time of the pulses is taken as zero.

The time deviation, or jitter, can be reduced in several ways. One is to make the time constants of the coupling circuits so long that there is no sag on the pulse tops; then there will be no undershoot, and therefore no tail to interfere with the second pulse. Another is to make the time constant so short that the tail has completely died away before another pulse could possibly occur. *Fig. 8* shows the effects of the time constant on the amount of jitter. The curve is normalized in terms of the baud. It was assumed in computing this curve that the pulses are of half-baud width, that they have rise times equal to 11.4 percent of a baud and that the fall times are zero. Furthermore, only the case of two pulses in a row is considered; therefore, aggravation of the jitter by pulses occurring several bauds earlier is neglected.

It is not possible in general to design an entire repeater with either very long or very short time constants. The next best thing is to retime the pulses so that jitter cannot accumulate from one repeater to another.

Retiming is accomplished by gating a timing pulse through an *and* gate. The timing and gating system is shown in *Fig. 9*. The *and* gate consists of diodes *CR103, CR113,* and the base-to-emitter diode of *Q113*. The gate is enabled by pulses at the collector of *Q105,* but the actual pulses passing through the gate and eventually appearing at the collector of *Q113* are from the oscillator *Q106*.

Transistor *Q106* and its associated components form a Hartley oscillator operating at the 1152 *kc* baud frequency. The oscillator is synchronized with the pulses by energy passing through diode *CR101* when the anode of this diode is more positive than —3 volts. The sine wave at the collector of *Q106* swings between the levels of —6 and 0 volts. When the waveform is more negative than —3 volts, energy feeds backwards from the oscillator through *CR101* to the collector of *Q105*. The coupling between *Q105* and *Q106* is fairly critical. If it is too tight, any jitter at *Q105* is fed right through the timing system. If it is too loose, the oscillator may fail to keep in synchronism with the baud frequency.

Transistor *Q107* is an emitter follower for decoupling the oscillator from the gate.

Variation of the oscillator's natural frequency with temperature is reduced by the 160 micromicrofarad capacitor, which is a temperature-compensating type selected to match the changes of the other circuit components. The overall frequency change with temperature is about 5 *kc*, measured with the oscillator in a free-running condition and *CR101* disconnected. This is a small enough variation so that energy from *Q105* can hold the oscillator in synchronism over a temperature range from —55 degrees Centigrade to +65 degrees Centigrade.

The Output Circuits

Retimed pulses from the collector of *Q113* are fed into a grounded emitter amplifier for voltage gain, and thence to a flip-flop where the pulse width is standardized. This assembly is shown in *Fig. 10*. Transistor *Q109* is normally off and *Q108* is normally on. When a positive pulse from diode *CR104* reaches the base of *Q108,* transistor *Q109* is turned on and energy flows to the base of the power output stage *Q110* through transformer *T102*. After a delay of 0.44 microseconds, the pulse that passes through the delay line turns *Q109* off again. In this manner, the width of the output pulses is standardized.

Transistor *Q110* is connected to its output transformer through a diode *CR106*. This diode is part of the fault locating system. If pulses appear with reasonable regularity at the anode of *CR106*, a bias is maintained on a transistor in the fault locating circuit (not shown) that keeps the fault locator relay in the open-circuited state. Failure of pulses at the anode of *CR106* permits the relay to make contact. When this happens, pulses from the good amplifier in the repeater reach the cathode of *CR106*. If this diode were not present, the fault detector would interpret these pulses as meaning that everything is in working order again, and the relay would open up once more. Thus, the only purpose of *CR106* is to prevent the fault locator from oscillating.

Several waveforms in the repeater are shown in *Fig. 11*. Part "A" of this figure illustrates the incoming waveform as seen across the secondary of transformer *T101*. In this, as in the other two photographs, a fixed pattern of four "1's" and four "0's" is used. *Fig. 11B* shows the signal at the collector of *Q105*. The positive-going, square-topped pulses are produced in response to transmitted "1's." The approximately sinusoidal signals present the rest of the time are evidence of energy feeding backwards through *CR101*, as explained earlier. Finally, *Fig. 11C* shows the output pulses, retimed and fixed in width, appearing at the cathode of *CR106*.

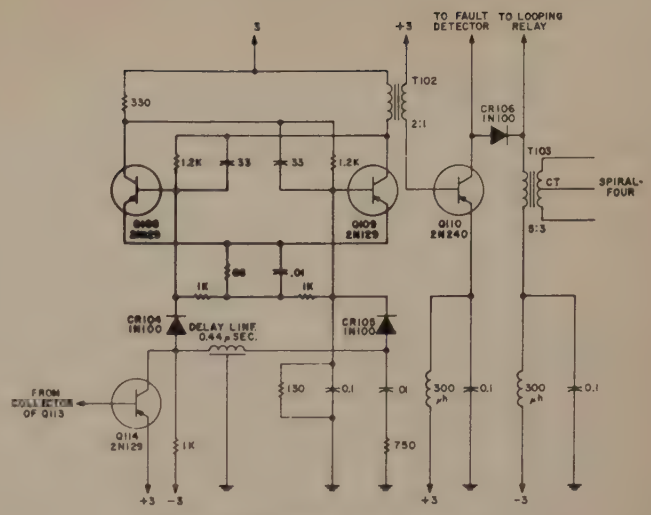
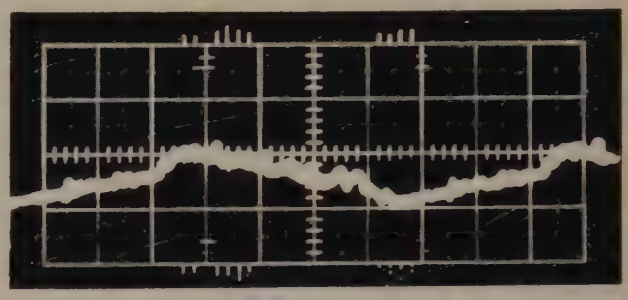
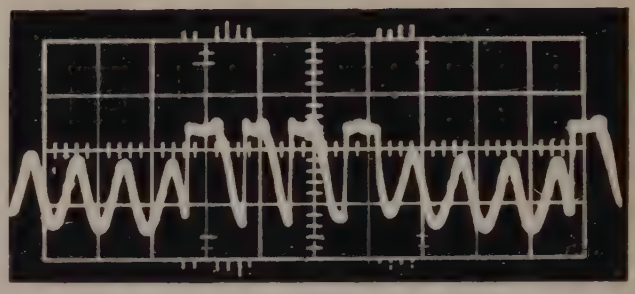


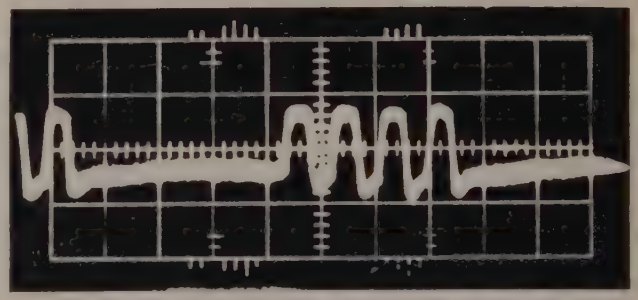
Fig. 10—Output circuitry.



(A)



(B)



(C)

Fig. 11—(A) Waveform across secondary of input transformer T101. Scale: each major division 0.5 volt or 1.0 microsecond. (B) Waveform at collector of Q105. Scale: each major division 1.0 volt or 1.0 microsecond. (C) Output pulses at cathode of CR106. Scale: each major division 5.0 volts or 1.0 microsecond.

Conclusions

The repeater is capable of operating at a baud rate of 1152 *kc* over the temperature range from —55 degrees Centigrade to +65 degrees Centigrade. The entire assembly of a pulse amplifier for each direction plus a common fault locator and power supply consumes about 400 milliwatts of power and uses 26 transistors. The repeaters operate with spiral-four cable at a spacing of one mile.

At the time of writing, the Comunications Department of the Raytheon Company is continuing work in this field with a similar *PCM* communications system designed to provide 96 channels of telephone service at a baud rate of 4.608 *mc*. This new system includes a number of additional features, such as provision for dropping one set of channels and inserting a new set at an intermediate point along a long-haul system.

Acknowledgments

The author acknowledges with sincere appreciation the support and suggestions of a number of his colleagues: in particular, Mr. William L. Hatton of the Raytheon Company, and Messrs. Martin Weinstock and Angelo Boniello of the United States Army Signal Research and Development Laboratories for whom the system was designed. The work described in this article was performed under Signal Corps Contract DA36-039-sc-73061.

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A New Type 150 KC Binary-Quinary Decade Counter with Neon Display†

ROY A. HEMPEL*

A new class of decade circuits has come into existence the past few years which promises to have a marked effect on counting and digital systems. This article examines one of these new Bi-Qui systems and presents detailed circuitry.

A NOVEL APPROACH is used in this economical Bi-Qui Decade to count to ten and to display this count using readily available low-cost neon lamps.

The standard method of counting to ten is to use four binary stages with one or two feedback loops.[1, 2] Without the feedback loops a count of 16 is obtained before recycling and with the feedback loops a count of ten is obtained. This technique is fairly standard in the industry today and will not be discussed in further detail.

The present circuit uses a two transistor binary driving a five transistor quinary and is termed a Bi-Qui decade. Decades in which the quinary drives the binary, termed Qui-Bi decades, have also been constructed. In either case only seven transistors are required, compared to the eight or more transistors normally used in commercial decades.

Two important features of this Bi-Qui decade are a bright, reliable neon display using relatively simple resistor networks; and a ten position electrical coincidence output circuit. A single operating voltage of +100 volts is all that is required. Total power dissipation for the Bi-Qui decade is less than 3½ watts.

A printed circuit model of the Bi-Qui decade is illustrated in the photograph. The detailed schematic is shown in *Fig. 2*. This model uses standard components throughout.

The front number display panel is plexiglass with silk-screened numbers and is fastened to the front upper and lower printed board corners. The entire display and board assembly is 3½″ high, 3½″ deep, and 1″ wide, and weighs less than 4 ounces.

The general operation of the decade including the neon circuitry and coincidence matrix is as follows:

The binary section (*Fig. 2*) is standard with the exception of the two criss-crossed diodes, *D1* and *D2*. These diodes boost the frequency response of the binary often more than 50% and do this with a minimum of circuit complexity. Type 1N34 diodes work quite well to beyond 150 *kc* when using 2N136 transistors; and type 1N191 diodes have been used in con-

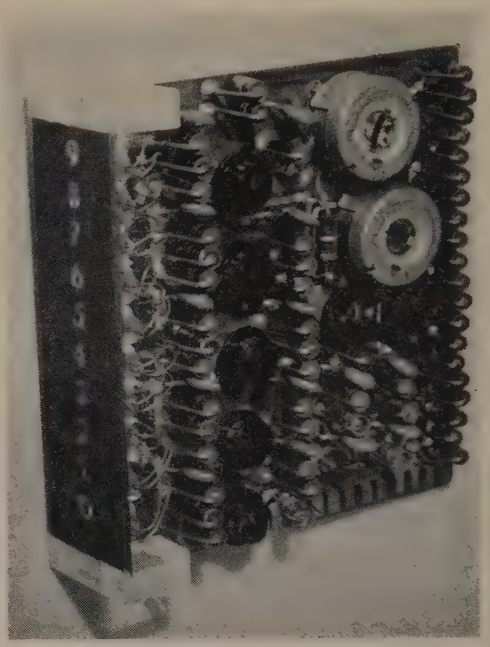

Photo of printed circuit model of the Bi-Qui decade.

COUNT	TRANSISTOR						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
0	OFF	ON	ON	ON	ON	ON	OFF
1	ON	OFF	ON	ON	ON	OFF	ON
2	ON	ON	OFF	ON	ON	ON	OFF
3	ON	ON	ON	OFF	ON	OFF	ON
4	ON	ON	ON	ON	OFF	ON	OFF
5	OFF	ON	ON	ON	ON	OFF	ON
6	ON	OFF	ON	ON	ON	ON	OFF
7	ON	ON	OFF	ON	ON	OFF	ON
8	ON	ON	ON	OFF	ON	ON	OFF
9	ON	ON	ON	ON	OFF	OFF	ON

Fig. 1—Transistor conduction for ten count conditions.

† Patents pending.

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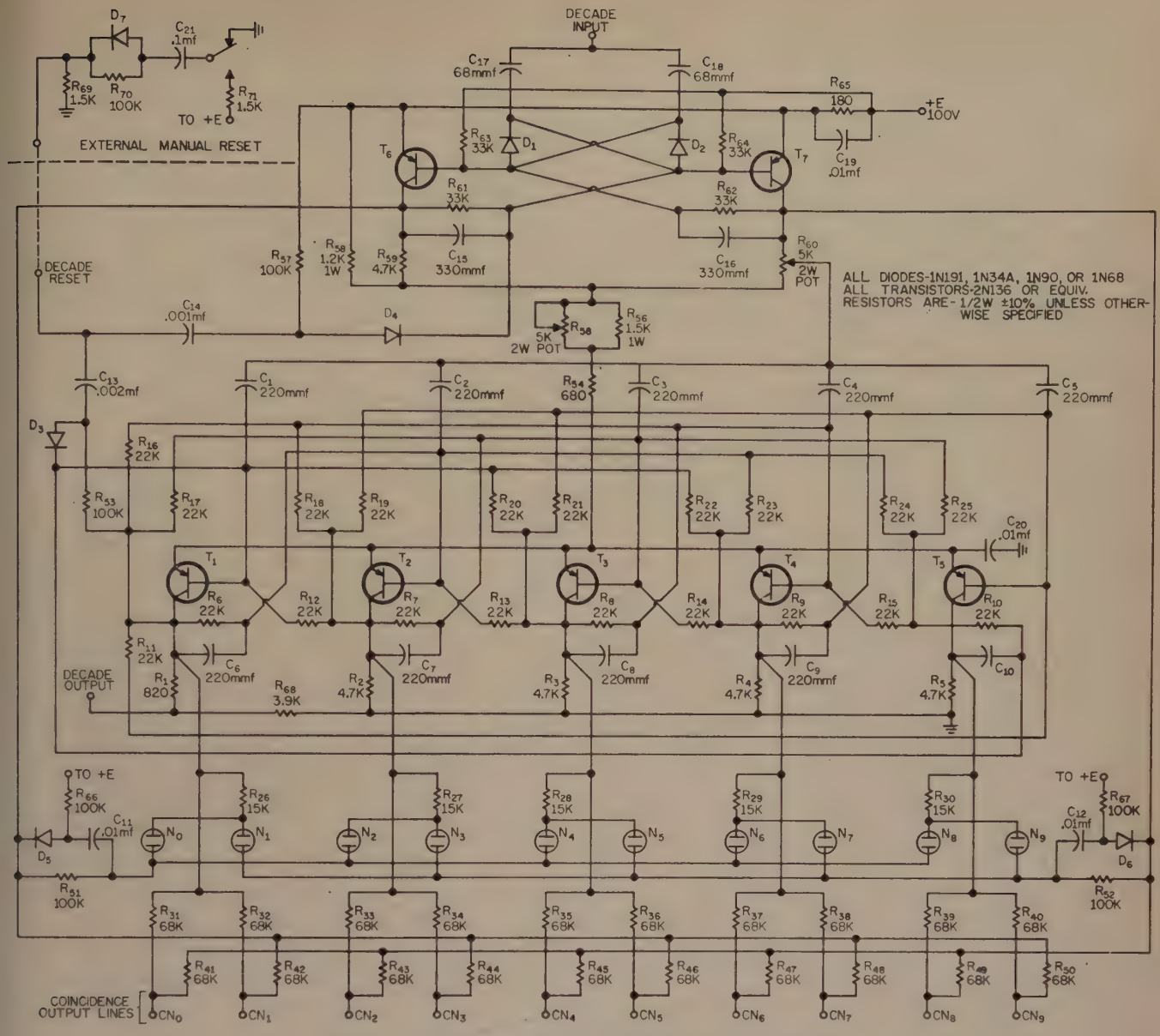

Fig. 2—Complete 150 *kc* decade counter schematic.

junction with 2N582 and 2N404 transistors for considerably higher frequency operation.

The quinary circuit is unusual in some respects and will be covered in detail. Several similar but not identical ring circuits have been published.[3, 4]

The base of each quinary transistor is connected to the remaining four quinary transistor collectors. For instance, in *Fig. 2*, *T1* base goes to each of the collectors respectively of *T2*, *T3*, *T4* and *T5*. There are 20 interconnecting quinary resistors, *R6* through *R25*, and their *22K* values have been selected for optimum quinary operation at 150 *kc*.

The quinary always has one transistor non-conducting or *off*, and four transistors conducting, or *on*. The binary, of course, always has one transistor *on* and one transistor *off*. *Fig. 1* shows the *on* and *off* states of each of the seven decade transistors for count zero through nine. Subsequent cycles beyond nine repeat the tabulations given in *Fig. 1*.

Starting with *T1 off*, the first negative pulse from *T7* passes through *R60* (which sets the correct pulse amplitude) and through *C1* to the base of *T1*, which is turned *on*. This pulse has no appreciable effect on *T2*, *T3*, *T4*, or *T5* which are already *on*. Transistor *T1* in turning *on* produces a positive pulse which passes through *C6* and turns *T2 off*. *T2* in turning *off* does not effect *T3*, *T4*, or *T5*.

Each time a negative pulse enters the quinary through *C1*, *C2*, *C3*, *C4*, and *C5* the above sequence of events is repeated until the *off* transistor has progressed from *T1* through *T5* and back again.

The direction of count in the quinary circuit is determined by the placement of condensers *C6*, *C7*, *C8*, *C9* and *C10*. In the circuit of *Fig. 2* the count proceeds to the right from *T1* to *T2*, *T2* to *T3*, *T3* to *T4*, *T4* to *T5*, *T5* to *T1*, and then repeats. By placing these condensers to the left of each transistor, that is, only across *R11*, *R12*, *R13*, *R14*, and *R15*, the count can be

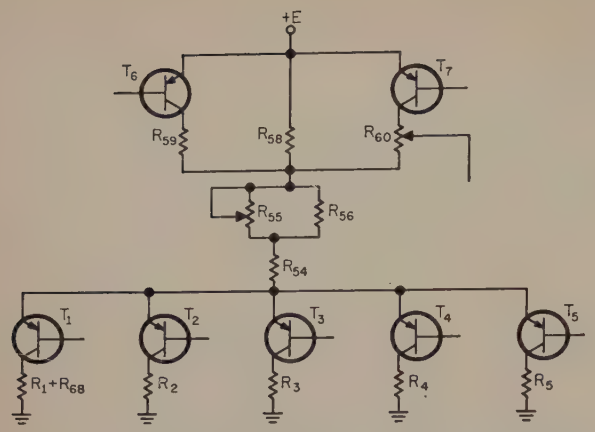

Fig. 3—Decade binary to quinary resistance coupling.

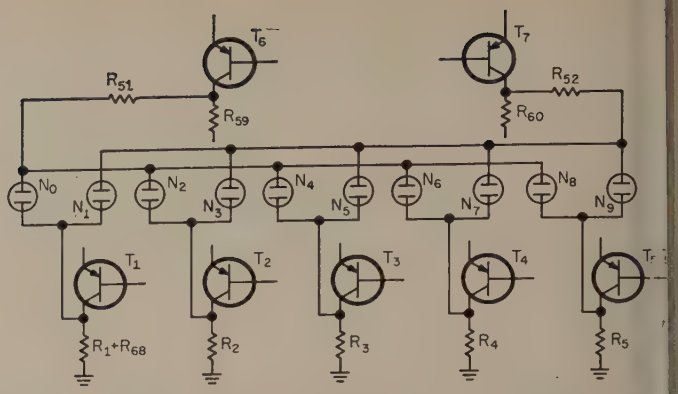

Fig. 4—Decade binary to quinary neon coupling.

made to go to the left in the reverse direction.

High-speed add-subtract counters have been built using condensers on both sides of the quinary transistors with suitable gating both in the quinary, and between the binary and quinary sections.

Using type 2N136 or equivalent transistors in the decade of *Fig. 2* 150 *kc* operation is readily obtained. The binary section alone works to more than 200 *kc* and the quinary section to 100 *kc* or higher. The quinary loading on the binary output lowers the overall system frequency response, but this can be overcome by using an emitter follower circuit between *T7* and the quinary section. However, for 150 *kc* operation an emitter follower is not necessary.

By using higher frequency transistors and lowering the quinary resistors *R1-R5* to 3.9 *K* and *R6-R25* to 18 *K*, and decreasing the values of *C1-C10* (depending upon transistors used), and going through a similar operation for the binary by decreasing *R59-R62* and *C15-C18*, the decade can be made to operate beyond 350 *kc*. Additional gating in the quinary input in series with *C1-C5* helps to boost the over-all decade frequency response to beyond 500 kc. These circuits will be covered in later articles.

An economical way to reset the decade manually is shown at the top left of *Fig. 2*. A positive pulse is applied to both *T1* and *T7* bases to turn these transistors *off*. All other transistors are *on*. The biasing and stability of the quinary are such that if *T3*, for instance, were initially *off*, the reset pulse would force *T1 off* and the change in biasing levels would force *T3 on*. The reset conditions for the decade are shown in *Fig. 1* to the right of count 0.

It is possible to use negative reset pulses, although a little more difficult, in which case the reset lines go to the base of *T6* and the collector of *T1*. This achieves the same decade conditions as before with *T1* and *T7* reset to the *off* conditions.

The decade count is displayed visually using ten type NE-2 or NE-2E neon lamps. The NE-2E lamps are favored because of their shorter ¾″ bulb length. More advanced displays such as the Nixie display, tungsten lamp display, 7 neon flat-plane display, etc. are all readily adaptable to the Bi-Qui decade configuration. However, for low cost and ease of construction, as well as reliability, it is hard to match the ten lamp display of *Fig. 2*.

The operation of the neon circuitry can best be explained by referring to *Figs. 3* and *4*. *Fig. 3* shows the method by which the binary network, resistor network, and quinary network are connected in series.

The resistor network is shown as *R54, R55, R56,* and *R58*, and is so arranged and selected as to provide approximately 30 volts across the binary and quinary respectively, the remaining 40 volts being applied across the *R54* and *R56* combination.

A simplified neon network is shown in *Fig. 4*. Each binary transistor connects to the top of five neons and each quinary transistor connects to the bottom of two neons.

It usually takes about 80 volts to fire the neons and the voltage must drop to about 55 volts before they extinguish. The binary collector output from each transistor is usually in the neighborhood of 18 volts change from *on* to *off* condition. The quinary output from each transistor collector is typically 15 volts change from *on* to *off* condition. This is a total of 33 volts effective change that can be applied to the neons to turn them *on* and *off*.

To understand more fully what takes place, refer to *Fig. 1*, count zero. *T1* and *T7* are *off* and all other transistors are *on*. Only neon *N-0* should light. From *Fig. 4*, *T6* will be *on* with a maximum collector voltage and *T1* will be *off* with a minimum collector voltage. Lamp *N-0* therefore has the maximum voltage across its elements, which is sufficient to fire it. All other lamps have a lower voltage and are *off*.

Resistor *R51* permits only one even numbered lamp to be *on* at a time; resistor *R52* permits only one odd-numbered lamp to be *on* at a time. In the present example for count zero, all odd-numbered lamps have minimum collector voltage from *T7* and maximum collector voltage from *T2, T3, T4,* and *T5*. This places minimum or extinguishing voltage across lamps *N-3, N-5, N-7* and *N-9* and they remain *off*. Lamps *N-2, N-4, N-6,* and *N-8* remain *off* both because of the lim-

iting action of *R51* and because their respective quinary collector voltages are a maximum, which places less than the required 'firing' voltage across these lamps.

Resistors *R26-R30* and networks *D5, C11, R66* and *D6, C12, R67* assist in turning the neons *on* and *off*. Decades can be constructed using only *R51* and *R52*, but the neons must be aged and selected more closely, and the decade supply voltages can vary only over ±2 volts. With the above neon resistor networks in addition to *R51* and *R52*, the neons can be selected for a broader difference in firing voltages, and the decade supply voltage can be permitted to vary over a ±4 volt range or more.

The neon lamps are ordinarily aged for 20 to 30 minutes running 1½ *ma* through them, then allowed to rest for several hours, and then selected for similar firing potential within 2 volts of each other. Pulse techniques for aging neon lamps[5] do a superb job if carried out properly and are suited for automation.

Electrical count indication is available from contacts *CN-0* through *CN-9* (*Fig. 2*). Each output line has two resistors associated with it. One resistor goes to a binary collector and the other to a quinary collector.

The coincidence line associated with the decade stored count will always put out a voltage lower than any other coincidence line. For example, on count zero, contact *CN-0* receives a minimum collector voltage from *T7* and *T1* which add together to give the lowest voltage of any of the remaining nine coincidence lines.

For frequencies above 100 *kc* small ceramic capacitors are usually added across some or all of resistors *R31-R50* to minimize coincidence output attenuation. The extent to which these capacitors are required depends upon decade component values, transistors used, and printed board wiring.

Many types of *p-n-p* and *n-p-n* decades for both ambient and 60° C operation have been constructed. These include 15 *kc* low cost decades, 150 *kc* decades as described in this article, 150 *kc* add-subtract decades, 500 *kc* decades, and 1.1 *mc* decades. Numerous displays have been developed including Nixie displays, tungsten 10-lamp displays, bright neon 10-lamp displays, and 7-lamp in-plane numerical displays.

Work is currently being conducted on modular packaging of these versatile Bi-Qui decades. Future articles will be published covering some of the outstanding features and circuits of the advanced decades and displays.

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High Gain Silicon Transistors

H. W. HENKELS* T. P. NOWALK*

Improvements in techniques of fabrication of transistors have led to success in the preparation of silicon transistors with extremely high gain. These are in essence cascaded transistors within single crystal elements. The units represent the first steps in the achievement of multifunction devices in monolithic blocks of semiconductors, i.e., the initial stages in the development of the molecular engineering concept. Two examples of such devices are given. The first device is a watt silicon transistor with current gain from 1000 to 500. The former value holds at one ampere; the latter value at about 2.5 amperes. Saturation resistance is 0.4 ohm. The second device has a current gain of between 400 and 600 at currents from 5 to 2 amperes. Voltage breakdown, collector-to-emitter, was 85 volts; the saturation resistance about 0.5 ohm. The properties of both devices will be described together with the types of high gain units that can be readily achieved with the new techniques.

WITHIN THE PAST THREE years, high power silicon transistors have been developed which will handle currents up to 5 amperes and block voltages up to 200 volts.† These have typical saturation resistances of 0.5 ohm at 5 amperes. The rating of 5 amperes is determined by consideration of the common-emitter current gain. The gain falls from values of 30 or 40 at low current levels to a minimum of 10 at the rated current. The current gain *vs.* current curve is shown in *Fig. 1*. The principal factors contributing to the fall in current gain are the reduction in emitter efficiency and transport factor at high current densities (and the resulting increase in base bias falloff). The range of current gains represents a compromise in the designed base thickness of the transistor, given attainable material diffusion lengths,

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†More recent devices rated up to 30 amperes.

in order to retain high blocking voltages. The emitter in the fused silicon power transistor described above is in the form of an annulus in order to minimize the base bias falloff effect. In the fused devices, the current gain of 10 and above can be achieved at 5 amperes while at the same time retaining high voltage characteristics and low saturation resistances permitting full utilization of the power handling capacity. The 5-ampere transistor has been discussed in further detail in Ref. (1).

In a diffused structure, high voltage characteristics can in theory be retained with base thicknesses designed to achieve higher current gains than in the fused devices. In practice, however, deterioration in lifetimes during diffusion have limited the current gains. It perhaps can be anticipated that higher gains will be achieved with refined diffusion techniques. However, the base bias falloff problem in diffused structures can be accentuated leading to limitations in current carrying capacity; and the saturation resistance is sufficiently high in the current range under discussion to make such devices unusable for the same reason and because of series collector resistance. A discussion of the factors influencing the design of fused and diffused power transistors has been given in Ref. (2). Reference (3) gives some of the recent results obtained with diffused structures.

To summarize the requirements of high-power, high-gain transistors, it is necessary that the gain be high at the rated current without sacrifice of voltage ratings and with saturation resistances compatible with the use of the devices at the rated currents. In the switching mode, a rough limitation on acceptable saturation resistance may be obtained by considering that an internal dissipation of perhaps 100 to 150 watts can be removed to the heat sink at useful ambient temperatures with reasonable size cooling fins in free air convection.

The prime objectives in the development of high-gain, high-power silicon transistors are three: (1) reduction in cost; (2) reduction in size and weight; (3) increase in reliability. High-power silicon transistors in the 5-ampere range require base drive of about 0.5 ampere. The 0.5-ampere silicon transistor is at present quite expensive, although this cost may be expected to decrease as production methods are refined. The 0.5-ampere silicon transistor is roughly one-half to two-thirds the size of the 5-ampere transistor. Consequently, a reduction in size and weight of 40% may be expected by the use of the high-gain 5-ampere unit. The most important factor is that involving reliability. The number of parts in the single unit is roughly one-half of that in the two-unit cascade. In addition, less external wiring and connections are required. The high-gain transistors achieved the objectives and represent the first step in obtaining multifunction devices in single semiconductor units. They represent initial stages in the development of the molecular engineering concept which is assuming increasing importance in component design.

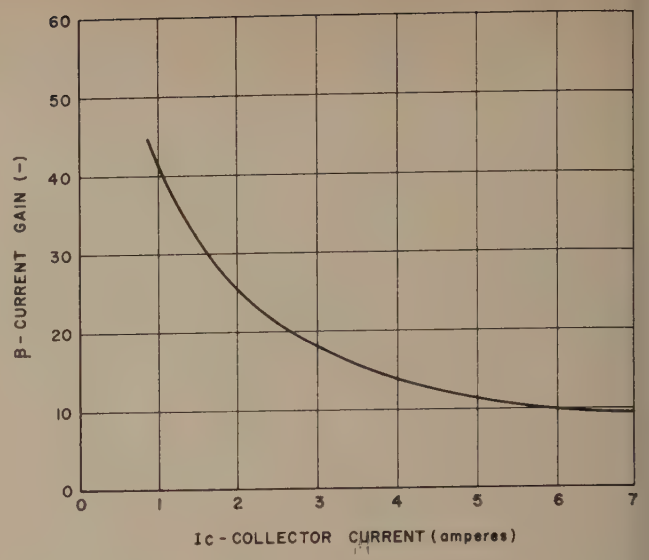

Fig. 1—Common emitter current gain *vs.* collector current for WX-1016 5 amp. silicon power transistor.

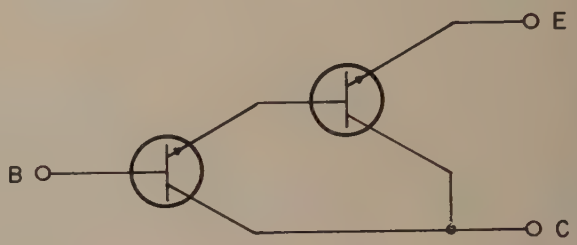

Fig. 2—Cascade structure equivalence for high-gain silicon power transistor.

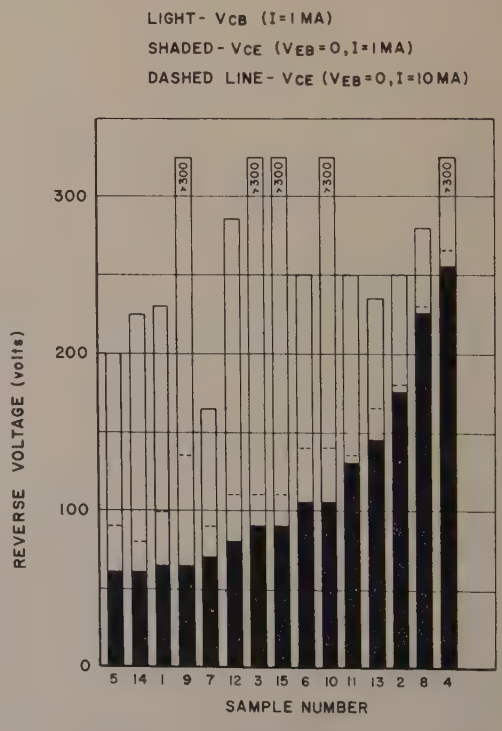

Fig. 3—Diode characteristics for 15 samples.

Structure

The units to be described are developmental models prepared to illustrate potentialities of high-gain units. The basic configuration and materials employed in devices discussed in Ref. (1) and (2) have been utilized in the design of the high-gain units. The emitter, base and collector configurations have been arranged to achieve the internal cascaded structure which may be represented by *Fig. 2*. It should be understood that cascading was not achieved by simply preparing individual transistors and connecting these within one case to give the cascading. The developmental case design has an overall diameter of 1¼ in. (the same dimension as that of the Westinghouse 2N-1016). The case is single-ended with a large stud for attachment to appropriate cooling structures.

Diode Characteristics

The results of a study of 15 units are given. The collector-base voltages at 1 *ma* current, the collector-emitter voltages (with $V_{EB} = 0$) at the same current and at 10 *ma*, and the emitter-base voltages at 10 *ma* were recorded. The data is shown in *Fig. 3*. The black segments give the collector-to-emitter voltages at 1 *ma;* the dashed lines are those at 10 *ma*. It should be observed that the knees of the characteristics are quite sharp as evidenced by the fact that the dashed lines are close to the 1 *ma* ratings (black segments). The leakage currents below the knee were of the order of 0.1 *ma*. It should be observed that at 1 *ma* the collector-emitter voltages ranged from 60 to 255 volts in the samples tested. The collector-base ratings were higher and ranged from 165 to over 300 volts. One-third of the units exhibited diode voltages over 300 volts. All of the above measurements were made at room temperature. Ratings at elevated temperatures are now being obtained. Emitter-base voltages are generally above 25 volts at the 10 *ma* current level.

Input Resistance

The common emitter input characteristic of a typical unit is shown in *Fig. 4*. Data are presented for input currents up to 10 *ma*. The collector voltage parameter is 0 and —5 volts. Incremental input resistance values were determined for input currents in the range of 1 to 4 *ma* and from 4 to 10 *ma*. At zero collector voltage, low current values approximated 50 ohms, the high current values 20 ohms; at collector voltages of —5 volts, the values were about 250 ohms and 80 ohms, respectively.

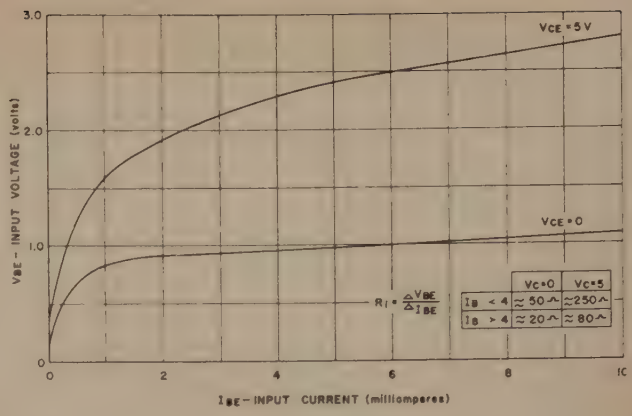

Fig. 4—Input characteristic of a typical high-gain silicon power transistor.

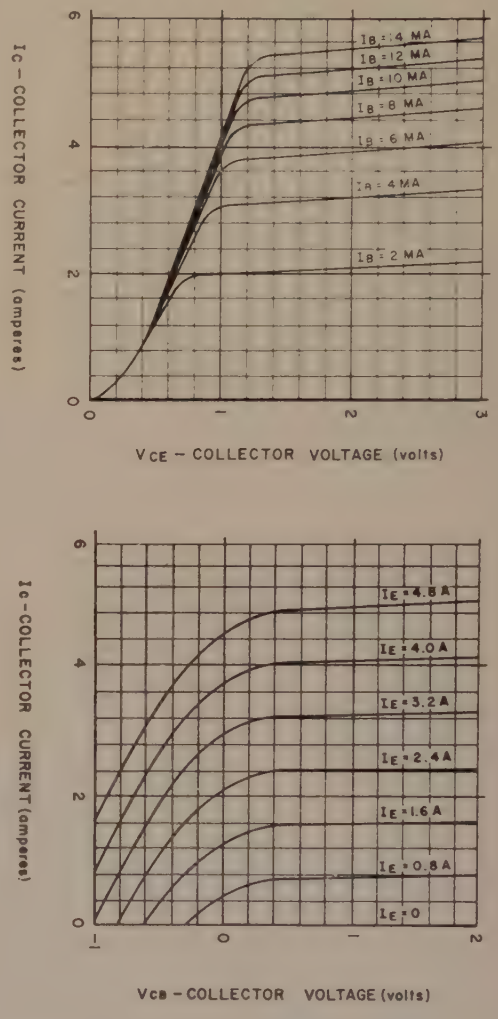
IB = 14 MA
IB = 12 MA
IB = 10 MA
IB = 8 MA
IB = 6 MA
IB = 4 MA
IB = 2 MA
IC - COLLECTOR CURRENT (amperes)
VCE - COLLECTOR VOLTAGE (volts)
IE = 4.8 A
IE = 4.0 A
IE = 3.2 A
IE = 2.4 A
IE = 1.6 A
IE = 0.8 A
IE = 0
VCB - COLLECTOR VOLTAGE (volts)

Fig. 5—Typical output characteristics, common emitter and common base configurations.

Output Characteristics

Figure 5 shows the output characteristic of a typical unit in the common emitter and common base configurations, respectively. The curves were taken on an American Electronics Transistor Tester.

In the first case, the *CE* family utilizes base drive of 2 *ma* per step where the horizontal axis (I_C) is calibrated for 2 amperes per large division (6 amp. full scale) and the vertical axis (V_{CE}) is calibrated for 1 volt per large division (3 volts full scale). *D-C* current gain ($\beta = I_C/I_B$) is taken at $V_{CE} = 3$ volts. From the figure, a beta of about 500 is evident at a collector current of 5 amp. The *a-c* current gain is, as expected, lower, being for the case illustrated about 200 at 5 amperes.

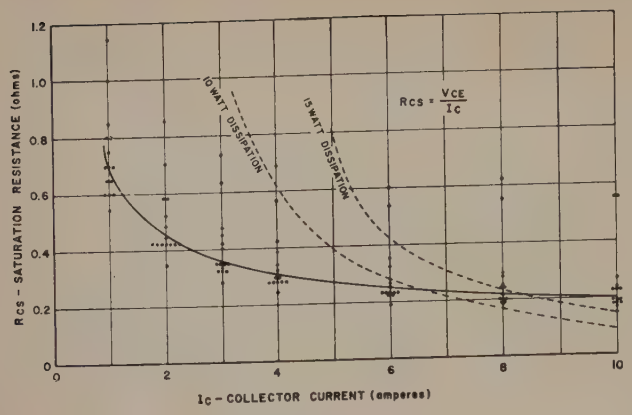

Fig. 6—Saturation resistance *vs.* collector current.

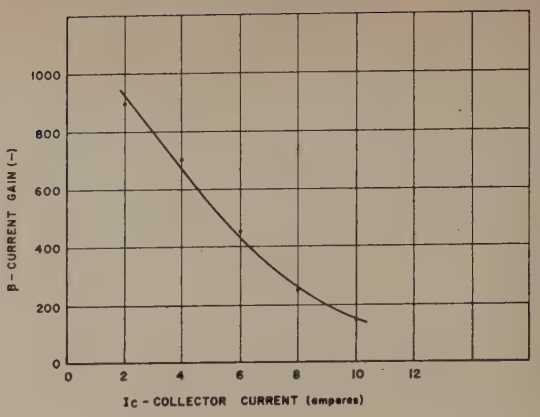

Fig. 7—Common emitter current gain *vs.* collector current

The important consideration is the low input current required to drive the transistor to high output currents. Thus, the device can operate from a very low power source. Assuming an input resistance of about 300 ohms and a base drive of 10 *ma*, a power supply rated at about 30 milliwatts is capable of controlling an output of 500 watts ($V_{CE} = 100$ volts, $I_C = 5$ amp). This is equivalent to a power gain of greater than 15,000.

The common base output characteristic indicates little change in alpha for the levels depicted. This is expected from the data illustrating the common emitter output characteristic. A computation of alpha at $I_C = 5$ amp. ($\alpha = \beta/[1 + \beta]$) gives a value of about 0.998.

Saturation Resistance

The limiting factor in power handling capacity of transistors in the power ranges under discussion is the internal heat loss. Generally, devices can be fabricated which are capable of controlling 5 or 10 amp. on a current gain basis. However, the internal thermal losses are usually too high to permit operation at the rated levels of current. For example, a rating of 15 watts dissipation was considered close to maximum for operation at useful ambient temperatures and with reasonably sized cooling fins. Based on losses in the collector region only, the maximum collector saturation resistance for $I_C = 5$ amp., where P_{diss} is approximated by $I_C^2 R_{CS}$, is 0.8 ohms; for $I_C = 10$ amp., 0.15 ohms. Thus, it is imperative that these losses be minimized if high power ratings are to be realized in actual usage.

Figure 6 shows the variation of saturation resistance with collector current for the 15 samples tested. The solid curve is a composite obtained by averaging the values for the thirteen units forming the closest group about given points.

The dashed curves indicate the 10 and 15 watt dissipation curves and are intersected by the solid curve at about 7 and 8.5 amp., respectively. From these data, the units can be rated conservatively at 5 amp. Special cooling arrangements will permit operation as high as 10 amp.

Current Gain (β)

Figure 7 is an approximate curve of current gain. Some units gave peak betas well over 1000. Several indicated relatively flat beta falloff curves over a range of several amperes. As noted above, the useable range will be primarily a function of heat transfer from device to cooling member. As shown previously, the current gain at 5 amperes is about 500. At 10 amperes, the current gain is still about 150. The power gain at 5 amperes in the switching mode is about 43 *db*. The complete circuit evaluation of the device will be carried out in the near future.

Summary

A new device, in the developmental stage, has been described wherein common emitter current gains over an order of magnitude higher than has previously been reported (about 500) is combined with low collector saturation resistance. The result is a power transistor with an output in the ampere range capable of operation from input sources of several *ma*. The device is further characterized by collector emitter voltages as high as 200 volts. Power gain at the 5-ampere level is 43 *db*.

The significance of the subject transistor cannot be evaluated solely on its high-gain characteristics. The unit illustrates the possibilities inherent in the molecular engineering concept. As one of the first samples of a practical device, it indicates a direction of effort along the lines of single devices to perform multiple functions with savings in cost, space and weight and increases in reliability.

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Transistor Switching Analysis

Dr. C. A. MEAD*

With the widespread application of junction transistors in switching applications, the need for a general method of analysis useful in the region of collector voltage saturation has become apparent. Linear equivalent circuits using lumped elements have long been used for small signal calculations of normally biased transistors, but a comparable method for saturated transistors has been lacking. Recently Linvill[3] proposed the method of lumped models which allow the analysis of complex switching problems with the ease of linear circuit calculations. The method is shown to be equivalent to a well-known linear equivalent circuit under normal bias conditions. Examples of the application of the method and the use of approximations are drawn from practical circuit problems. Emphasis is placed upon the understanding of the physical phenomena involved, a necessary prerequisite to intelligent circuit design.

Part 1

WITH THE FIRST ANALYSIS of a junction transistor triode, it was recognized that such a device was capable of *symmetrical* operation; that is, either the "emitter" junction or "collector" junction could act as a source of minority carriers in the base region. Thus modes of operation are available in a transistor which have never existed in the vacuum tube. For example, a saturated transistor (both emitter and collector forward biased) will carry signals well in both directions, while if both junctions are reverse biased, essentially no signal is allowed to pass in either direction. The inherently low voltage drop across a saturated transistor makes possible the control of very high powers with low dissipations. For these reasons, transistors find switching service a most important and useful application.

The first detailed analysis of the large signal properties of transistors was done by Ebers and Moll.[1] Later Linvill[3] proposed a technique by which the same results may be obtained, but which has the advantage that a linear model is used and physical insight into the behavior of the device is more readily gained. The purpose of the present article is to extend this method to the general treatment of diodes and transistors in practical circuit applications, to present results in special cases of importance, and to illustrate applications of the analysis in sufficient detail to be generally useful to the design engineer.

Requirements of the Analytical Method

Let us examine the requirements on a method of analysis to be used in problems of this nature. Clearly, what is needed is a model, similar to an equivalent circuit such as used for small signal work, yet appropriate for all conditions encountered in transistor operation; i.e., either junction may be either forward or reverse biased, currents may be either small or large, *a-c, d-c,* or both. Together with a model, the method must include a procedure for evaluating elements in the model and for making approximations where an exact analysis would be too cumbersome.

Furthermore, in order to be of general utility, the method of analysis should possess the following qualities:

(a) The principal variables should be related in a linear manner so linear circuit theory may be used.

(b) Non-linearities in the system should be easily and accurately approximated by a simple piecewise linear idealization.

(c) Elements in the model should be readily obtainable in terms of simple, easily-measured device parameters.

(d) Variables in the model should possess physical significance, and results of the analysis should enhance one's physical insight into the problem.

(e) The model should reduce to familiar form for special cases, e.g., normal bias, small signal.

The variables necessary to solve normal semiconductor problems are:

1. Junction voltage
2. Junction current
3. Minority carrier density

provided we deal only with devices in which the diffusion current predominates. Transistors of this type are typically used in switching service where the method is most generally useful.

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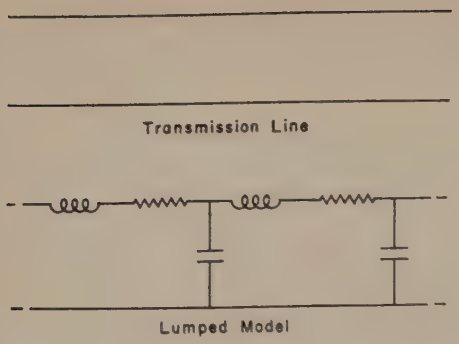


Fig. 1—Transmission line and equivalent lumped element representation.

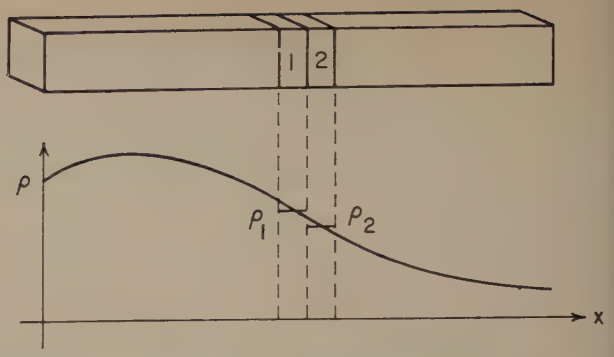


Fig. 2—Semiconductor bar with excess minority carrier distribution.

Review of Basic Processes

Before launching into the details of analysis, let us briefly review the basic processes which occur within a semiconductor. If we limit our discussion to one-dimensional diffusion flow, a complete description of the motion of minority carriers within the material consists of:

1. The continuity equation for minority carriers

$$\frac{\partial N}{\partial t} = \frac{N_0 - N}{\tau} + D\frac{\partial^2 N}{\partial x^2}$$

where N is the density (number per unit volume) of minority carriers as a function of x and t

N_0 is the density of minority carriers at thermal equilibrium

τ is the "lifetime" of minority carriers

D is the diffusion constant of minority carriers

x is the distance through the semiconductor

2. The condition that any macroscopic volume element of the material be electrically neutral.

Introduction to Lumped Models

The continuity equation is a partial differential equation, involving both time and space derivatives, and its solutions are in general both difficult and messy, resulting in carrier densities at all points as a function of time.

One is reminded of the transmission line problem where again a partial differential equation must be solved and the results are voltage (or current) at any point on the line as a function of time. Pursuing the analog still further, the analysis of a transmission line is greatly simplified if we are content to find *approximate* voltages and currents at *certain specified* points along the line instead of *exact* voltages and currents at *all* points along the line. Since normally only the ends of the line are of interest, such a procedure seems highly desirable. To this end we approximate the line by a ladder network as shown in *Fig. 1*.

The line possesses a series inductance and resistance per unit length, and a shunt capacitance per unit length. These distributed parameters are represented in the ladder network by the *lumped elements L, R* and *C*. Thus we have created a *lumped model* as an approximation to the real transmission line. The voltage at any node, or the current through any element may be obtained by standard circuit analysis techniques. Hence, we have transformed a problem in partial differential equations into a problem in simple circuit theory.

Each section of the lumped model corresponds to a given length of transmission line. As the number of sections is increased, the length of line to which each section corresponds is decreased and the accuracy of the approximation is improved. In the limit, as the number of sections becomes infinite, each section represents an infinitesimal length of time and we are again faced with the solution of a partial differential equation. Perhaps the most significant feature of the lumped model is that the approximations have been made before any equations were written, and each element in the model has definite physical significance.

Semiconductor Lumped Model

In order to simplify our expressions for minority carrier flow, it is convenient to write the continuity equation in terms of a new variable, the *excess density*, $N - N_0$.

$$\frac{\partial(N - N_0)}{\partial t} = -\frac{(N - N_0)}{\tau} + D\frac{\partial^2(N - N_0)}{\partial x^2}$$

For a p-type semiconductor: $N \doteq n$, $N_0 = n_p$
Therefore,

$$\frac{\partial \eta}{\partial t} = \frac{\eta}{\tau} + D\frac{\partial^2 \eta}{\partial x^2} \qquad \eta = n - n_p$$

For an n-type semiconductor: $N = p$, $N_0 = n_n$
Therefore,

$$\frac{\partial \rho}{\partial t} = -\frac{\rho}{\tau} + D\frac{\partial^2 \rho}{\partial x^2} \qquad \rho = p - p_n$$

Now let us examine the physical significance of each term in the continuity equation. Consider a long bar of n-type semiconductor with unit cross-sectional area containing volume elements 1 and 2.

Suppose within the bar there exists a distribution of excess holes $\rho(x)$ as shown in *Fig. 2*, which is a function of x but independent of y and z. The volume elements will possess average excess densities ρ_1 and ρ_2 respectively.

Storage. Due to the charge neutrality requirement, an excess density of minority carriers implies an equal excess density of majority carriers. Thus a *change in minority excess density with time produces a majority carrier current into the volume element.* Such a change in density with time is represented by the first term in the continuity equation, and the resulting current is the *rate of change of stored charge* in the volume element.

Recombination. According to the simple linear recombination law, the recombination rate is proportional to the excess density. Again the charge neutrality condition requires that if the minority carrier density remains fixed, for each recombination a new majority carrier must enter the volume element. However, in order for the minority carrier density to remain fixed, a new minority carrier must also enter the volume element. Thus, since the carriers possess opposite charges, the net effect of recombination is to bring minority carrier current into the volume element and force an equal majority current out of the volume element. This effect is represented by the second term in the continuity equation.

Diffusion. If the slope of the carrier excess density curve is greater at the left boundary of the volume element than at the right boundary, there will be a net minority carrier diffusion current into the volume element. This effect is represented by the last term in the continuity equation. Since the diffusion current is proportional to the gradient of the excess density, the current flowing from element 1 into element 2 will be approximately proportional to $(\rho_1 - \rho_2)$.

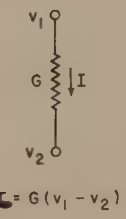
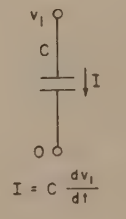
We may state the continuity equation, then, as follows:

> The sum of currents flowing out of a given volume element due to
>
> a) change in stored charge
> b) recombination of carriers
> c) minority carrier diffusion
>
> is equal to zero.

When so stated it is clear that the continuity equation is merely Kerchhoff's law for a continuous system. However, we have seen that such a system may be approximated by a lumped model in which the network node equations replace the continuity equation. We may therefore construct such a model for our bar of semiconductor. Lumped models of this type were first proposed by Linvill.[3]

Lumped Model Elements. The elements required for such a lumped model are clearly of a different nature than those of electric circuit theory. The variables are excess density and current rather than voltage and current. It should always be borne in mind that the semiconductor lumped model is analogous, not identical, to its corresponding electric circuit.

TABLE I

Symbol for Element	Electrical Analogy
	
$I = G(\rho_1 - \rho_2)$	$I = G(v_1 - v_2)$
	
$I = C\frac{d\rho_1}{dt}$	$I = C\frac{dv_1}{dt}$

However, the same methods are available for the solution of either type of problem.

The types of elements required may be summarized as in Table I. Clearly the excess densities are the direct analogies of voltages in an electrical circuit.

The lumped model for our bar of semiconductor may be constructed in exactly the same manner as for the transmission line, as shown in *Fig. 3*. Here ρ_1 and ρ_2 are the average excess hole densities in volume elements 1 and 2. G_1 and C_1 represent recombination and storage in volume element 1, while G_2 and C_2 represent recombination and storage in volume element 2. G_{12} represents the diffusion of holes from volume element 1 into volume element 2. It will be noticed that the lines are not wires but are defined as regions of constant excess density. The bottom line is defined as the zero excess density, and current flowing in this line is majority carrier current. This convention follows from the definitions of the elements and the effects which they represent. Although the lumped model elements are linear, it should be borne in mind that the excess density ρ is constrained to be greater than $-p_n$ at all times, since the actual density cannot become negative. This restriction will introduce nonlinearities later when specific problems are considered.

As a check on the lumped model, let us assume a uniform excess minority carrier density in the semi-

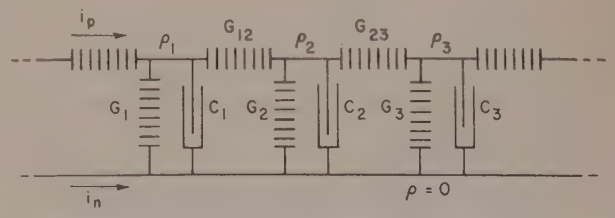
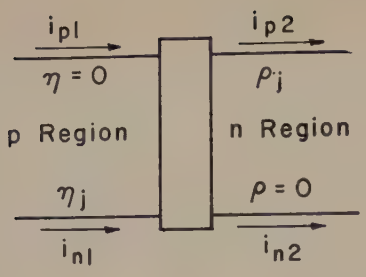


Fig. 3—Lumped model of semiconductor bar.



$$i_{p1} = i_{p2}$$
$$i_{n1} = i_{n2}$$
$$\rho_j = p_n(e^{qv/kT} - 1)$$
$$\eta_j = n_p(e^{qv/kT} - 1)$$

Fig. 4—Model of *p-n* junction.

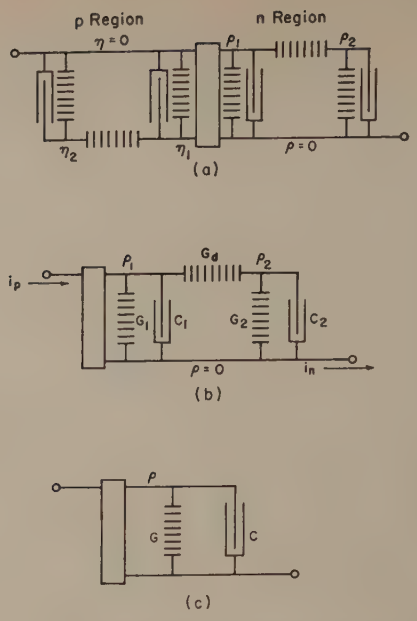


Fig. 5—Development of diode model.

conductor bar. Under these conditions the continuity equation becomes

$$\frac{\partial \rho}{\partial t} = -\frac{\rho}{\tau}$$

which has the solution

$$\rho = \rho_0 e^{-t/\tau}$$

From the lumped model

$$\rho_1 = \rho_2 = \rho_3 \text{ etc.}$$

Thus no current flows in the diffusion conductances and we may write Kerchhoff's law as, for example

$$\rho_2 G_2 + C_2 \frac{\partial \rho_2}{\partial t} = 0$$

or

$$\frac{\partial \rho}{\partial t} = -\frac{G_2}{C_2} \rho_2$$

which has the solution

$$\rho_2 = \rho_0 e^{-\frac{G_2}{C_2} t}$$

and similarly for the other junctions. Thus the lifetime τ may be identified with the time constants of the lumped model parallel elements

$$\frac{1}{\tau} = \frac{G_1}{C_1} = \frac{G_2}{C_2} = \frac{G_3}{C_3} \text{ etc.}$$

It is now clear that the basic diffusion process within the semiconductor is extremely simple, analogous to an *RC* ladder network where all capacitors are connected to ground, and all shunt elements have time constant τ. No inductive elements are present, since the diffusion process cannot support a propagating wave. Our lumped approximation is complete and we are in a position to solve any problem where the initial conditions or boundary conditions on the excess density are known, by the application of simple circuit theory.

Boundary Conditions, the *p-n* Junction. In a semiconductor device such as the transistor, the boundary conditions on minority carrier excess density are generally determined by the voltage across certain *p-n* junctions in the structure. Depending upon the type of semiconductor material, temperature, operating current density and other factors, the value of excess density determined by a junction with a certain applied potential may vary. However, in most instances the recombination within the junction is small and the following expressions are sufficiently accurate for practical application:

$$\rho_j = p_n (e^{qv/kT} - 1) \quad (1a)$$

$$\eta_j = n_p (e^{qv/kT} - 1) \quad (1b)$$

where

ρ_j is the excess hole density at the n side of the junction
η_j is the excess electron density at the p side of the junction
k is Boltzmann's constant
T is the absolute temperature
v is the voltage across the junction, being taken as positive when the junction is forward biased

In this approximation the hole and electron currents entering the junction from one region emerge undiminished at the opposite side of the junction.

Thus the junction provides an excess density essentially independent of current, or acts as an *excess density generator* controlled by the junction voltage. The analogy in electric circuit theory would be a *voltage generator* controlled by some other variable in the system, as frequently used in small signal equivalent circuits for active devices. The symbol for such a junction is shown in *Fig. 4*. Here again the top lines carry hole current, and the bottom lines carry electron current.

P-N Diode

A *p-n* junction diode consists not only of the *p-n* junction itself but also of the adjoining *p* and *n* regions. Thus the diode model must include lumped element network sections for both regions as well as the junction "excess density generator." The number of sections used for each region is determined by the accuracy required and the fortitude of the analyst. An appropriate compromise is usually obtained at one or two sections per region. A two-section model is shown in *Fig. 5a*. As before, the junction boundary densities ρ_1 and η_1 are determined by the junction voltage through the exponential junction law.

In cases where the conductivity of one region is much greater than that of the other, carrier injection into the high conductivity region is small and may be neglected. For example, if the *p* region is of very high conductivity compared with the *n* region, n_p is very small compared to p_n (since $p_p n_p = n_i^2$, a constant for given temperature). Thus η_1 will be very small compared to ρ_1, and only hole current need be considered. Under these conditions, considerable simplification in the lumped model is possible, i.e., the elements corresponding to the *p* region may be deleted, as shown in *Fig. 5b*.

For many practical applications, sufficient accuracy is obtained by the use of only one lumped section, as shown in *Fig. 5c*. In this model the capacitance *C* represents minority carriers stored near the junction and the conductance *G* represents the combined effect of recombination near the junction and diffusion away from the junction and subsequent recombination. As will be seen, the great virtue of the single section model is the ease with which the element values are determined.

Diode Small Signal Response. If the diode is forward biased and a small *a-c* signal $v_1 e^{j\omega t}$ is superimposed on the *d-c* bias voltage v_0, we may write the injected excess density

$$\rho = p_n(e^{qv/kT} - 1)$$

where $v = v_0 + v_1 e^{j\omega t}$.

Now if $v_1 << kT/q$ we may expand the exponential and retain only the first two terms

$$\rho \approx p_n \left[e^{qv_0/kT} \left(1 + \frac{q}{kT} v_1 e^{j\omega t} \right) - 1 \right]$$

Thus the *a-c* component of excess density is

$$\rho_1 e^{j\omega t} \approx \frac{q}{kT} v_1 p_n e^{qv_0/kT} e^{j\omega t}$$

if the *d-c* current through the diode is much greater than its saturation current, the excess density will be much greater than p_n, and the exponential term in the expression for excess density will be large compared to unity. Thus the *d-c* component of excess density becomes

$$\rho_0 \approx p_n e^{qv_0/kT} \tag{2}$$

Combining these two expressions, the amplitude of the *a-c* excess density is

$$\rho_1 \approx \rho_o \frac{q}{kT} v_1 \tag{3}$$

From the lumped model of *Fig. 5c*, the current through the diode is composed of a *d-c* bias component

$$I = \rho_o G$$

and an *a-c* component

$$i_1 = \rho_1 (G + j\omega C)$$

But from equations 2 and 3

$$i_1 = \frac{qI}{kT} \left(1 + j\omega \frac{C}{G} \right) v_1$$

Thus the time constant C/G may be determined by one simple small signal measurement on the diode, i.e., the impedance rolloff frequency

$$\omega_h = \frac{G}{C}$$

To determine the magnitude of *G* we may measure the *d-c* junction voltage required to produce a certain current. If the current is much larger than the saturation current of the diode

$$I = \rho G \approx p_n G e^{qv/kT}$$

or

$$p_n G = I e^{-qv/kT}$$

It will be noticed that we are not able to determine either p_n or *G* individually from external measurements on the diode, but only their product. However, for this reason we need not know the individual values if we are interested only in voltages and currents, since expressions for these external variables involve only the product. Hence our two simple measurements on the diode, small signal impedance rolloff frequency and *d-c* voltage drop for a given *d-c* current, serve to completely determine the lumped model which is now applicable to all operating conditions.

(To be continued)

Introduction to Semiconductor Theory and Reverse Breakdown*

C. A. ESCOFFERY, Ph.D.**

Part 2

Extrinsic Conduction

The type of conduction discussed so far, and illustrated by *Fig. 5a,* is known as *intrinsic conduction.* Another way of controlling the current is by the effect of very small amounts of impurity atoms introduced into the crystal lattice of the semiconductor. This type of conduction, known as impurity or *extrinsic conduction,* makes use of intermediate, localized energy levels within the forbidden energy gap (*Fig. 5, b* and *c*).

If the impurity level lies just above the (bottom) valence band, we have what is known as an *acceptor level* and the semiconductor is called *p*-type (*Fig. 5b*). Consider, for instance, a sample of pure silicon doped with a very small amount of boron. Boron belongs to Group III of the Periodic Table of the Elements and has only three valence electrons.[9] When a boron atom replaces a silicon atom in the crystal lattice it cannot supply the normal quota of four valence electrons that each silicon atom does. A positive hole carrier is therefore created around each boron atom. Since there is now an excess of holes, the current will be carried mainly by them.

Referring again to *Fig. 5b,* we see that the new energy level (indicated by broken lines to signify that it is not continuous, but confined to the individual boron atoms) can readily *accept* electrons from the nearby full valence band. The current is carried by holes left behind in the valence band when electrons move out. It can be visualized as a lateral movement of holes within the valence band, towards the negative electrode.

Similarly, we can produce *n*-type silicon by doping with a pentavalent element such as antimony, which belongs to the fifth group of the Periodic Table. The antimony atoms donate five valence electrons instead of silicon's four, and the extra electrons occupy discrete energy levels, close to the upper, conduction band (*Fig. 5c*). These levels are called *donor levels* because they readily donate electrons to the nearby band, where they are able to conduct a current.

Boron is called an accePtor and antimony a doNor. A useful mnemonic device is to recall that the *p* in acceptor and the *n* in donor are associated with positive and negative carriers, respectively.

P-N Junctions

The boundary between adjacent *p*- and *n*-material within the same single crystal is of great theoretical interest and of tremendous practical importance. Energy band diagrams can be calculated and drawn for *p-n* junctions, and the properties and characteristics of these junctions can generally be interpreted more easily by means of such diagrams.

Fig. 6 is a schematic diagram of the energy relationships of a *p-n* junction in, say, silicon. For simplicity, the hole concentration on the *p*-side is shown as approximately the same as the electron concentration on the *n*-side. Furthermore, the acceptor and donor levels have been omitted, but it should be understood that these levels exist and are responsible for the large number of holes in the (valence band of the) *p*-side and the large number of electrons in the (conduction band of the) *n*-side, respectively.

A study of *Fig. 6* reveals that the *p*-side of the silicon is higher up on the electronic energy scale than the *n*-side. This indicates that, relative to the *n*-side, the *p*-side has a larger negative energy. At first sight, this appears contradictory but what happens is the following.

Imagine the *p* and *n* sides of the junction as though they were separated. Each side has no net charge because there is electrical neutrality. That is, in each side the total number of mobile carriers is balanced by an equal number of immobile ionized atoms.

Now, imagine the two sides as coming into contact. The *p*-side becomes negatively charged because the excess of positive holes that it possesses tends to dif-

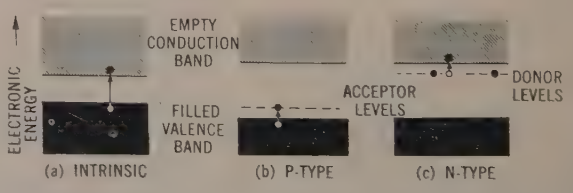


Fig. 5—Electronic energy diagrams for semiconductors. Black and white circles represent electrons and holes, respectively.

*This is a reprint of an article which appeared in the "Zener Diode Handbook," published by International Rectifier Corp.

**International Rectifier Corporation

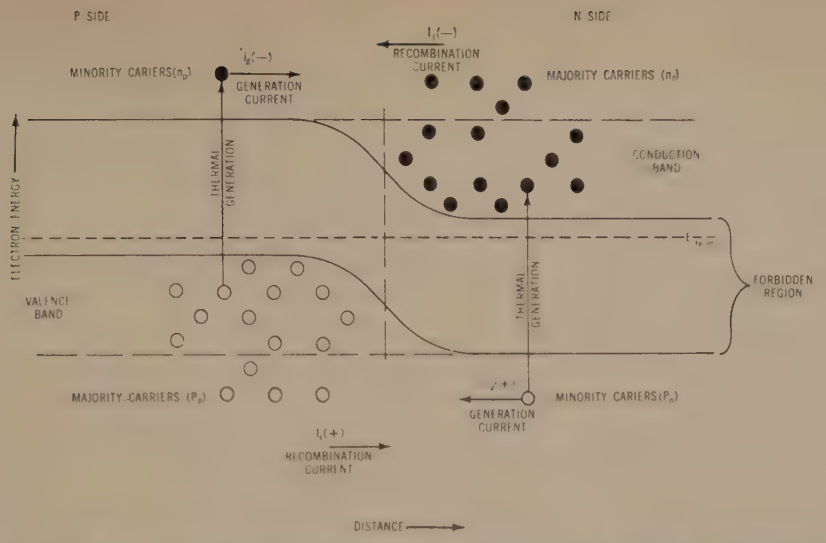


Fig. 6—Electron energy diagram for a *p-n* junction at thermal equilibrium and no applied bias. White and black circles represent holes and electrons, respectively.

fuse over to the negative side (Eq. 1). This process leaves behind less positive holes than required for equilibrium, which is equivalent to making the *p*-side slightly negative.

Similarly, the excess electrons on the *n*-side tend to diffuse over to the *p*-side (according to Eq. 1), thereby leaving the *n*-side positively charged. Consequently, the *n*-side is shown on the diagram as being more positive (that is, having less electronic energy) than the *p*-side.

The diffusion of holes (majority carriers) away from the *p*-side, and of electrons (majority carriers) away from the *n*-side, eventually is balanced by the counteracting effect of electrical attraction of the charged surfaces for minority carriers. The latter, which have been thermally generated, tend to drift back across the *p-n* junction because there is a lower potential for them on the opposite side of the junction.*

We thus have two opposing effects in equilibrium and there is no net current: The forward, diffusion current is balanced by a reverse, generation current. This balance holds both for holes and electrons, so, in essence, we have four currents in equilibrium.

The forward, diffusion current of carriers is also called a recombination current, because it is determined by the recombination rate of holes and electrons. A hole, for instance, that leaves the *p*-region starts out as a majority carrier but when it reaches the *n*-region it automatically becomes a minority carrier. It then diffuses for an average *lifetime* τ_p before recombining with an electron and losing its identity.

In addition, the average distance the holes penetrate† the *n*-region is called the *diffusion length*, L_p, and it is related to the hole lifetime by the following relationship

$$L_p = \sqrt{D_p \tau_p} \tag{8}$$

where D_p is our old friend, the hole diffusion constant (*Cf.* Eq. 1).

A similar situation holds for the movement of electrons into the *p*-region, and the diffusion length of electrons (in the *p*-region) is given by

$$L_n = \sqrt{D_n \tau_n} \tag{9}$$

where D_n is the electron diffusion constant and τ_n is the electron lifetime.

Fig. 6 illustrates the situation for the *p-n* junction in equilibrium without any applied voltage. The overall current can be considered as being made up of two parts, one corresponding to drift and one resulting from diffusion. The drift effect is given by Eqs. 4 and 5. The diffusion effect is obtained from Eq. 1, where the particle flow can be converted to current by multiplying by the electronic charge, *e*, to yield the following diffusion currents:

$$i_p = -eD_p \frac{dp}{dx} \tag{10}$$

$$i_n = +eD_n \frac{dn}{dx} \tag{11}$$

where i_p is the hole diffusion current and i_n is the electron diffusion current. The electron current has a positive sign because the negative electronic charge yields an equivalent current opposite in direction to the electron flow.

Combining Eqs. 4, 5, 10, and 11 we find that the

*The electrons can be considered as sliding down the electronic potential hill. The holes, since they are oppositely charged, will easily slide up hill. A simple analogy is given by the motion of marbles and of air bubbles within a horizontal tube filled with water: Tipping the tube causes the marbles to roll downwards and the bubbles to float upwards. Similarly, if the cars in Fig. 1 had no brakes, tilting the ground would cause the cars to roll downhill and the spaces to move uphill in the opposite direction.

† Actually L_p is the average distance required for the hole concentration, P_n, to drop to $\frac{1}{e}$ of its original value.

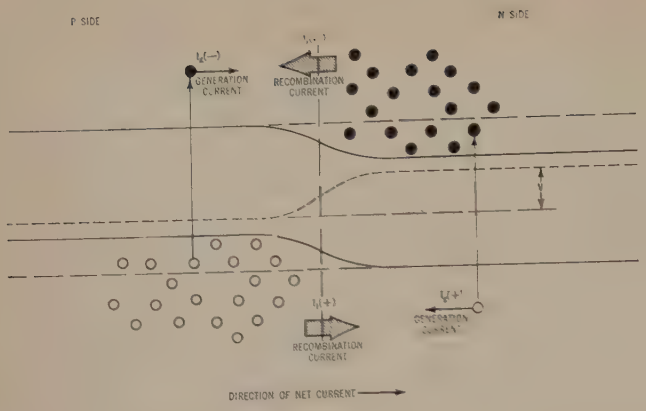


Fig. 7—Electron energy diagram for a *p-n* junction biased in the forward direction (*p*-side positive).

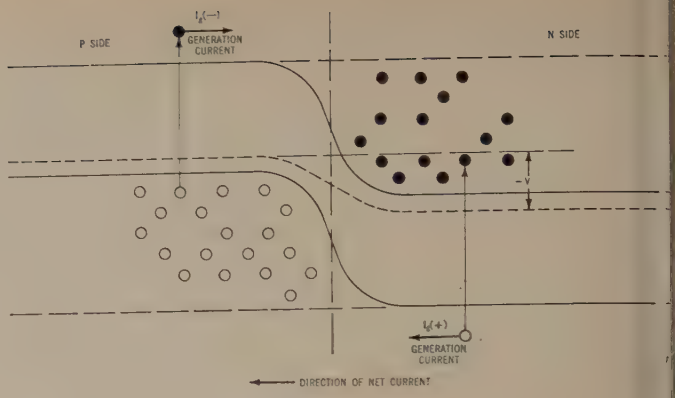


Fig. 8—Electron energy diagram for a *p-n* junction biased in the reverse direction (*p*-side negative).

overall hole and electron currents are given by

$$i_p = pe\mu_p E - eD_p \frac{dp}{dx} \tag{12}$$

$$i_n = ne\mu_n E + eD_n \frac{dn}{dx} \tag{13}$$

The electrostatic field E arises, as discussed above, from the charging action on opposite sides of the *p-n* junction as a result of diffusion processes.*

Let us now consider what takes place when an outside voltage V is applied to the *p-n* junction. In the forward direction, that is making the *p*-side positive, the situation is illustrated by *Fig. 7*. It can be seen that by making the *p*-side more positive with respect to the *n*-side, we have depressed the energy bands on the *p*-side and raised them on the *n*-side. Consequently, the potential barrier between the two sides has been decreased (by the amount V) and majority carriers are able to surmount the junction barrier. As shown in the figure, a large supply of majority carriers is available for diffusion, resulting in a large forward current.

*The charging action also gives rise to an electrostatic potential, φ_o, commonly known as the built-in potential. It is related to the field by the following equation

$$E = -\frac{d\varphi_o}{dx} \tag{14}$$

Silicon has typical built-in potentials of about 0.5 to 0.8 volts.

It can also be shown that φ_o is related to the intrinsic carrier density n_i by the following expression:

$$\varphi_o = \frac{kT}{e} \ln \frac{n_n\, p_p}{n_i^2} \tag{15}$$

where the subscripts n and p refer to the concentrations of the carriers in the *n*- and *p*-areas outside the transition region of the junction. Since n_i increases very rapidly with temperature (Eq. 7), the built-in potentials tend to drop to zero as the temperature is raised.

The net forward current is actually determined, however, by the concentration of the minority carriers. Consider the diffusion of electrons into the *p*-region, where they become excess minority carriers. According to Eq. 11, the diffusion current is strongly dependent on the *gradient* of the electron density. In order to maintain a steep concentration gradient, the excess electrons which penetrate (are injected into) the *p*-region must be disposed of. This is accomplished through recombination.

On the average, each electron diffuses a length L_n into the *p*-region and survives for a lifetime τ_n. Then it recombines with a hole (which is the majority carrier) and both the electron and the hole are withdrawn from circulation. In order to preserve electrical neutrality, another hole (from the positive contact electrode) automatically replaces the hole that recombined. This last process leads to a flow of majority carriers (holes in the *p*-region) and accounts for the greater part of the current in the *p*-side (Fig. 9).

When a voltage is applied in the reverse direction (*p*-side made negative), the situation is illustrated by *Fig. 8*. It can be seen that the difference in height between the energy bands of the *p*- and *n*-sides has increased to the point where there is little or no diffusion of majority carriers across the junction. The only current now flowing is a very small one, due to thermally generated minority carriers which are attracted across the junction by the electrostatic field. This current gives rise to the reverse leakage current in a rectifier.

The current is again determined by minority carriers. Only those generated (on an average) within a diffusion length can reach the junction and drift over to the electrostatically charged opposite side. As shown by Eq. 16, the current is essentially independent of voltage and saturates at I_s, the value given by Eq. 17. For an ideal *p-n* junction operated under certain simplifying conditions, Shockley[12] has derived a very useful expression which enables the *I-V* characteristics to be predicted in terms of basic semicon-

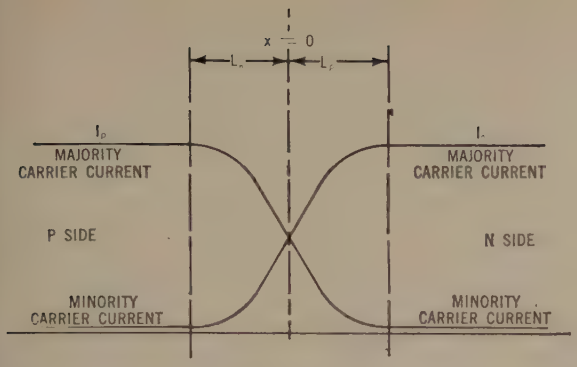


Fig. 9—Schematic representation of the distribution of electron and hole currents across a *p-n* junction.

ductor properties. This expression is

$$I = I_n + I_p = I_s\left[\exp\left(\frac{eV}{kT}\right) - 1\right] \qquad (16)$$

where I = junction current — amp/cm^2
V = junction voltage — volts

and the saturation current is

$$I_s = e\left[\frac{D_p\, p_n}{L_p} + \frac{D_n\, n_p}{L_n}\right] \qquad (17)$$

where, respectively, D_p and D_n are the hole and electron diffusion coefficients; p_n and n_p the concentration of holes and electrons in the n- and p-regions; and L_p and L_n the hole and electron diffusion lengths.

Eq. 16 indicates that the forward current (V positive) increases exponentially with voltage, whereas the reverse current (V negative) saturates at $-I_s$, corresponding to the thermal generation of minority carriers within a diffusion length of each side of the junction.

At low voltages, the hole current in the forward direction depends directly on the hole diffusion coefficient and the hole density in the n-material, but inversely as the diffusion length. A similar reasoning applies to the electron current.

Fig. 9 indicates how the electron and hole currents vary in the semiconductor with a biased *p-n* junction: Within the transition region of the junction, the currents are controlled by minority carriers; outside of that region, the drift of majority carriers predominates.

The ideal theory as given by Eq. 16 agrees fairly well with experimental data on germanium junctions operated at low levels and at room temperature. It does not apply to silicon at room temperature or to germanium at low temperature. Consequently, a number of modifications and extensions have been made to the simple theory.[13, 14]

In the case of silicon *p-n* junctions, it is found that the reverse leakage current is not as small or as constant as Eq. 17 predicts, and it is necessary to consider the effects of spontaneous carrier generation and recombination within the barrier region.*

Likewise, departures from Eq. 16 occur when the junctions are operated at high forward current densities, and modifications to the simplified theory are again required. The analysis becomes fairly difficult since non-linear differential equations are involved and various approximations have to be made.[13]

*This has been shown to be theoretically possible.[15] Since the generation current is dependent on the volume of semiconductor material in which generation occurs, and since the junction barrier width increases with applied reverse bias, so too does the reverse current of silicon diodes increase slightly with voltage.

(To be continued)

Applications Engineering Digests

APPLICATIONS ENGINEERING DIGEST NO. 47

Selecting Transistors and Drive for a DC-DC Converter; Bendix Semiconductor Products, Long Branch, New Jersey.

Transistor Selection Criteria

1. Collector-Emitter Breakdown Voltage:

The maximum open base breakdown voltage, $\mathbf{BV_{ceo}}$, must be equal to or higher than the battery voltage. If $\mathbf{BV_{ceo}}$ is not given, the maximum rated $\mathbf{V_{ce}}$ should be 1.3 times the battery voltage for a bridge circuit. In a push-pull application the breakdown voltages should be twice those for the bridge circuit. This eliminates the possibility of operating a transistor in the negative resistance region of the $\mathbf{I_c}$ versus $\mathbf{V_{ce}}$ characteristic and also takes care of the transient voltage spikes usually encountered. For DC-DC bridge converters with a small leakage inductance and small currents, the maximum rated $\mathbf{V_{ce}}$ may be as low as 1.1 times the battery voltage.

2. Base-Emitter Breakdown Voltage:

The maximum emitter-base voltage must be greater than the drive voltage surges across the emitter junction.

3. Collector Current:

The maximum collector current rating must be more than the battery current.

4. Cutoff Frequency (Common Emitter):

Common emitter cutoff frequency, $\mathbf{f_{ae}}$, should be high compared with the actual switching frequency in order to achieve low power dissipation during switching. A transistor having an $\mathbf{f_{ae}}$ of 3 *kc* is usually adequate for converters operating at frequencies up to 1*kc*. It should be noted here that the

switching time is highly dependent upon the circuit configuration, and components other than the transistors.

5. Power Rating:

The power dissipation, P_c, of a DC converter transistor can be divided in the following manner: the power dissipated during the "on" time, P_1, during the "off" time, P_2, and during the switching time, P_3. $P_c = P_1 + P_2 + P_3$ must be lower than the rated maximum power dissipation for the existing mounting base temperature.

P_1—Selecting a transistor with low saturation voltage decreases P_1. The power dissipation during the "on" condition, P_1, is principally the saturation voltage times the battery current. For higher temperatures the change in P_1 is negligible.

P_2—During the "off" time, the power dissipation, P_2, is approximately the battery voltage time I_{cbo} (collector-base cutoff current). Collector cutoff current increases with temperature, so that for critical applications where high temperatures are involved, the transistor should be selected for low values of collector cutoff current. Transistors so selected also show little variation in h_{FE} with temperature. The power dissipation in these transistors is lower during the "turn off" transient.

P_3—The power dissipation during switching time is a function of many variables and is therefore difficult to predict. The variables are:

a) Transformer core material
b) Base current
c) Drive surges due to capacitors
d) Transformer leakage inductances
e) Collector current
f) Junction temperature
g) Oscillation frequency.

In a properly designed 250 watt DC-DC bridge converter working at 1.2 *kc* and 60 volt input, P_3 should not exceed 1 watt at 30°C mounting base temperature for a 2N677B transistor. During switching the peak power can be very high, but because of the very short switching time, the junction temperature does not rise significantly, so that the use of the average power dissipation is valid.

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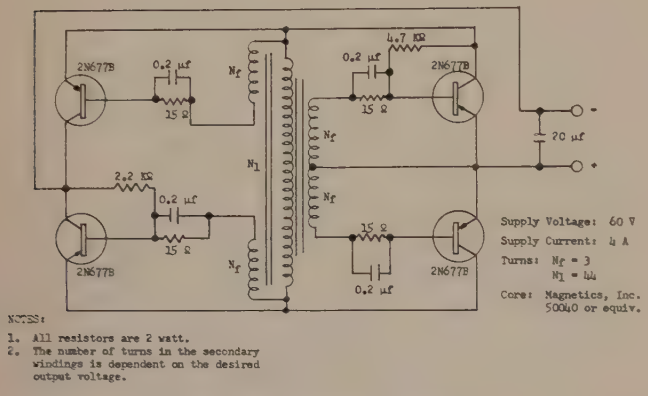

Fig. 47.1—Bridge Circuit.

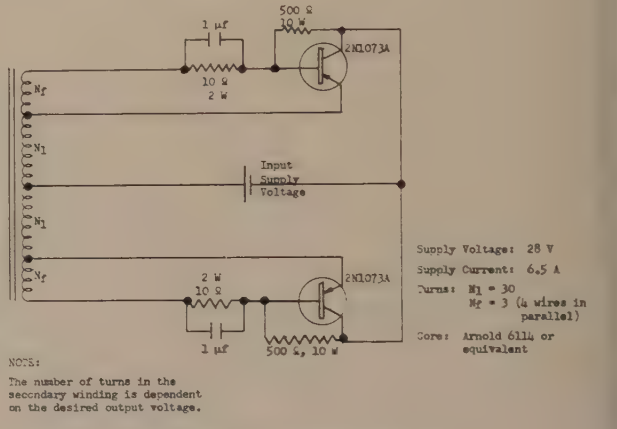

Fig. 47.2—Push-Pull converter.

APPLICATIONS ENGINEERING DIGEST NO. 48

Series Operation of Silicon Rectifiers; Fansteel Metallurgical Corp., No. Chicago, Illinois.

The D-C voltage required for many applications will necessitate more than one cell in series in each arm of the particular rectifier circuit being used. Where it is necessary to series rectifiers in a circuit arm, it is important to assure that correct division of voltage is obtained.

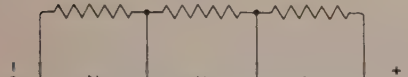

Fig. 48.1—Voltage division using resistors.

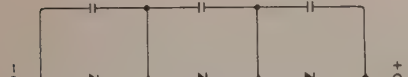

Fig. 48.2—Voltage division using capacitors.

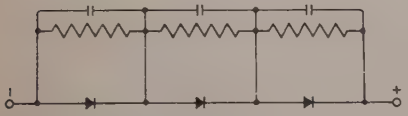

Fig. 48.3—Combined capacitive and resistive voltage dividers.

Resistors are most commonly used to force division of the reverse voltage across series silicon cells. These resistors are placed in parallel with each cell, as shown in *Fig. 48.1*, and a resistance value equal to one-half of the minimum reverse resistance of the rectifier cell will assure satisfactory voltage division. The minimum resistance is determined by the ratio of the maximum peak reverse voltage and the maximum peak reverse current at the maximum operating temperature.

Capacitive voltage dividers are important in high voltage application where the distributed capacitances may result in uneven voltage distribution during transient operation. The capacitors will reduce the effect of uneven voltage distribution resulting from differences in the recovery times of the series silicon rectifier cells. The capacitance connected across the cell, as shown in the circuit diagram. *Fig. 48.2* must be larger than the junction capacitance.

Capacitance voltage dividers may be combined with resistive dividers, as shown in the circuit, *Fig. 48.3*, for some applications.

If only a small number of cells are required in series, transformers employing multiple secondary windings may be used, as shown in *Fig. 48.4*. Each secondary would be used to supply a circuit having one series cell and the output of these circuits connected in series to supply the required higher voltages.

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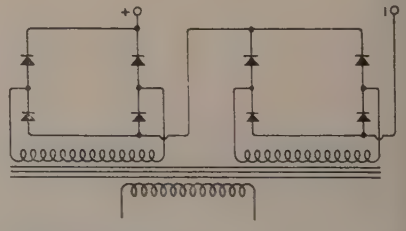

Fig. 48.4—Series connection of a small number of cells.

Theory, Parameters, and Ratings of the p-n-p-n Silicon Controlled Rectifier: Texas Instruments Incorporated, Semiconductor-Components Division, Dallas, Texas. (Jearld L. Hutson)

Definitions of Parameters and Ratings

$\mathbf{V_F}$—*Forward voltage* is the voltage drop between the anode and cathode at any specified $\mathbf{I_F}$, when the device is in the "on" condition. See *Fig. 49.1.*

$\mathbf{I_F}$—*Forward Anode Current* is any value of positive current which flows through the device when it is in the "on" condition. See *Fig. 49.1.*

$\mathbf{I_{F(off)}}$—*Forward "off" Current* is the anode current which flows when the device is in the "off" condition with a positive anode voltage applied. See *Fig. 49.2.*

$\mathbf{V_R}$—*Reverse Anode Voltage* is any value of negative voltage which may be appled to the anode. *Rated* $\mathbf{V_R}$ is less than the reverse avalanche bias voltage and is the maximum peak inverse voltage of the device. *Fig. 49.3* illustrates the rated $\mathbf{V_R}$ of a typical unit.

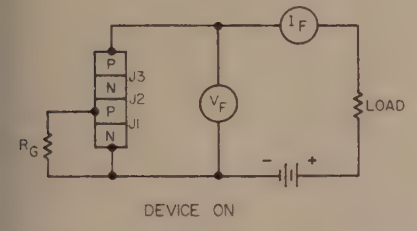

Fig. 49.1—Forward Voltage and Forward Anode Current.

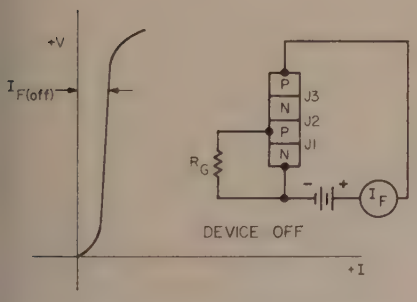

Fig. 49.2—Forward "off" Current.

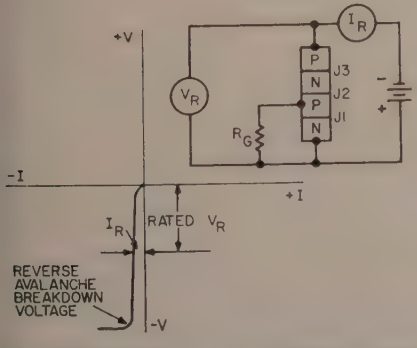

Fig. 49.3—Reverse Anode Voltage and Reverse Current.

$\mathbf{I_R}$—*Reverse Current* is the negative current which flows through the device at any specified conditions of $\mathbf{V_R}$ and temperature. *Fig. 49.3* illustrates the reverse current, $\mathbf{I_R}$, at rated $\mathbf{V_R}$.

$\mathbf{V_G}$—*Forward Gate Voltage* is the voltage drop across the gate-to-cathode junction at any forward gate current. See *Fig. 49.4.*

$\mathbf{I_G}$—*Forward Gate Current* is any value of positive current which flows into the gate, with a shunt resistance ($\mathbf{R_G}$) between the gate and cathode. See *Fig. 49.4.*

$\mathbf{V_{GR}}$—*Reverse Gate Voltage* is any value of negative voltage which may be applied to the gate. Rated $\mathbf{V_{GR}}$ is less than the reverse breakdown voltage of the gate-to-cathode junction and is the maximum peak inverse voltage of the gate. See *Fig. 49.5.*

$\mathbf{BV_F}$—*Forward Breakover Voltage* is the value of positive anode voltage at which a controlled rectifier will switch into the "on" state, with a shunt resistance between the gate and cathode. $\mathbf{BV_F}$ may also be considered the forward avalanche voltage. See *Fig. 49.6.*

$\mathbf{I_H}$—*Holding Current* is the minimum anode current required to sustain the device in the "on" condition. See *Fig. 49.6.*

$\mathbf{T_j}$—Junction temperature, in a p-n-p-n device, is usually considered to be a composite temperature of all three junctions. Since all parameters of the device are temperature dependent, its operating $\mathbf{T_j}$ is very important. In analyzing any circuit using controlled rectifiers, a good estimate of $\mathbf{T_j}$ should be the first consideration.

$\mathbf{t_r}$—*Rise Time* is the interval during which the output pulse changes from 10% to 90% of its maximum amplitude.

$\mathbf{t_{(off)}}$—*Turn-off time* is the interval between the start of the turn-off and the instant at which $\mathbf{BV_F}$ may be reapplied, the device having been previously in the "on" state. Turn-off time is a function of the following:

1) $\mathbf{I_F}$ and its rate of decay. As forward current and its rate of decay increases, $\mathbf{t_{(off)}}$ increases.

2) Junction temperature. $\mathbf{t_{(off)}}$ increases as the junction temperature increases.

3) Reverse recovery current. If the device is subjected to reverse bias immediately following a condition of forward conduction, a reverse recovery current will flow through the device, analogous to normal diode recovery current. As the reverse recovery current becomes greater, $\mathbf{t_{(off)}}$ becomes smaller.

4) Rate of rise of reapplied forward voltage and its maximum amplitude. As the rate of rise and the amplitude of reapplied forward voltage increase, $\mathbf{t_{(off)}}$ increases.

A simple test circuit for determining $\mathbf{t_{(off)}}$ under different conditions is illustrated in *Fig. 49.7.*

The operation of this circuit is as follows:

The approximate value of R_L is calculated according to the desired operating E_{bb} and I_F. The value of R_C is not critical, but is in general about 10 R_L.

R_R is the reverse recovery current-limiting resistor and is variable from zero to several ohms. Resistor R_S, across which the reverse recovery current is viewed, is non-inductive, as are both

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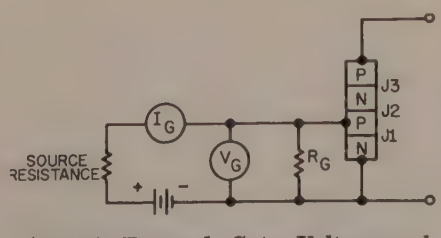

Fig. 49.4—Forward Gate Voltage and Forward Gate Current.

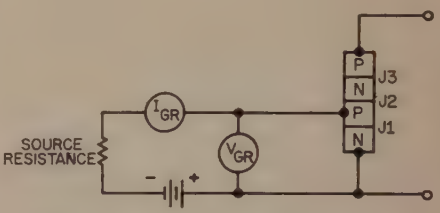

Fig. 49.5—Reverse Gate Voltage.

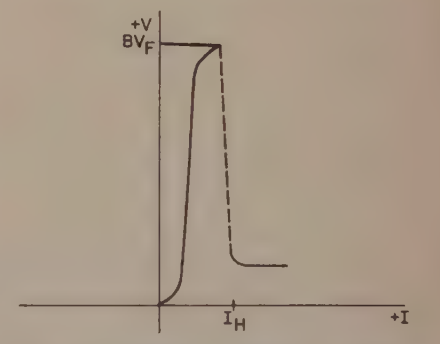

Fig. 49.6—Forward Breakover Voltage and Holding Current.

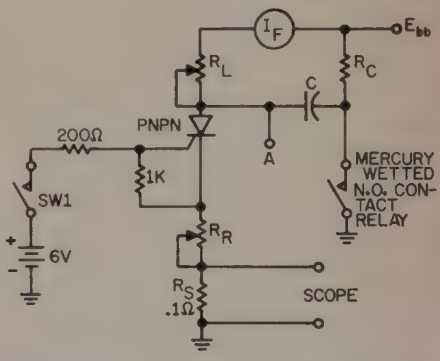

Fig. 49.7—Test circuit for determining t_{off}.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from May 13, 1958 to June 10, 1958. In subsequent issues, patents issued from Dec. 3, 1957 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

May 13, 1958

2,834,701 Semiconductor Translating Devices—R. A. Gudmundsen, J. Maserjian Jr. Assignee: Hughes Aircraft Company. A transistor having a thin base region is made by fixing a mechanical backing to the base region of the translator body, said backing comprising the same semiconductor and having the same conductivity type but lower resistivity than the base region.

2,834,877 Automatic Gain Control Circuits —W. Milwitt. Assignee: R.C.A. In this device a voltage or current controlled variable impedance voltage divider network utilizing varistors provides an A.G.C. voltage source for the amplifier stages of a receiving system.

2,834,878 Controllable Reactance Systems —L. L. Burns Jr., E. O. Keiger. Assignee: R.C.A. A controllable variable capacitance circuit employing a semiconductor amplifier.

2,834,884 Wave Guide with Crystal Diode Socket Having Captive Clamping Means —C. P. Domenichini, J. Bakura. Assignee: Raytheon Manufacturing Company. A quickly attachable and readily removable means for keeping the crystal diode in contact with the terminal of a conductor leading from the wave guide to a point where the heterodyned output is utilized.

2,834,899 Radioactive Resistor—V. E. Ragosine. Assignee: Sprague Electric Company. A high resistance radioactive resistor having a large range over which the current voltage characteristic is linear and having no self generating *e.m.f.'s.*

2,834,903 Electroluminescent Lighting Device—S. Roberts. Assignee: General Electric Company. A device including a coated glass plate, a layer of nitrocellulose over said electrically conducting coating, an insulating layer over the nitrocellulose, a layer of electroluminescent phosphor dispersed in polystyrene, and a conducting layer over the polystyrene layer.

May 20, 1958

2,835,444 Multiplication Circuit—N. B. Blake, W. H. Cox. Assignee: Sun Oil Company. A simple multiplication circuit capable of four quadrant multiplication.

2,835,558 Recovery of Selenium—L. E. Vaaler. Assignee: Diamond Alkali Company. The separation of selenium from source materials by converting the selenium in the original material into soluble selenates, reacting the soluble material with a precipitating agent to form insoluble selenates, and then reducing the insoluble selenates to elemental selenium.

2,835,612 Semiconductor Purification Process—W. E. Taylor. Assignee: Motorola Inc. An improved zone refining process in which an alloying agent is introduced into the molten zone in order to influence the distribution coefficient of the impurities in the charge.

2,835,613 Method of Surface-Treating Semiconductors—P. W. Haayman. Assignee: North American Philips Company Inc. A method of forming a *p-n* junction in a semiconductive body by bringing said body into contact with a molten substance containing a desired impurity and effecting diffusion of the impurity into said body.

2,835,614 Method of Manufacturing Crystalline Material—R. G. Pohl. Assignee: The Tayland Corporation. A method of manufacturing ingot lengths of crystalline semiconductor material having uniform longitudinal impurity distribution without requiring controlled variation in the temperature pattern and crystal growth rate.

2,835,615 Method of Producing a Semiconductor Alloy Junction—B. A. Leinfilder Jr., L. D. Favro. Assignee: Clevite Corporation. A method for producing a high current-carrying germanium indium alloy junction in which oxygen at the germanium indium interface has been removed.

2,835,740 Arrangement of Subscriber's Line Circuits—A. Heetman. Assignee: North American Philips Company Inc. A transistorized circuit for use in an automatic telephone system, said circuit having the feature, that the line detector current is not low and that cross talk is suppressed during the calling position.

2,835,748 Negetative Feed-Back Transistor Amplifier—J. Ersink, J. Verhogen. Assignee: North American Philips Company Inc. A stable amplifier providing low distortion which uses transistors of the current amplifying and non-current amplifying type.

2,835,750 Transistor Amplifier—H. Volkers, G. Rosier. Assignee: North American Philips Company Inc. An amplifier in which collector current variations due to temperature and premagnetization of the emitter coupled matching transformer core are suppressed.

2,835,810 Crystal Rectifier—M. C. Waltz. Assignee: Bell Telephone Laboratories. A crystal rectifier having a coaxial line input portion, a semiconductive wafer and a spring wire rectifying contact, said rectifier having a configuration such that the spring wire assembly and cavity portion effects an impedance match for the coaxial portion.

2,835,828 Regenerative Transistor Amplifiers—J. H. Vogelsong. Assignee: Bell Telephone Laboratories. An amplifier which provides regenerated pulses with waveshapes that are nearly independent of the input pulse waveshapes.

2,835,829 Circuit for Switching High Voltage Using Cascade Connected Low Voltage Transistors—R. P. Sourgens, R. A. Choilet. Assignee: None. A transistor switching apparatus capable of switching a current produced by a source having a voltage greater than that which may be applied between the emitter and the collector of the transistors of said apparatus.

2,835,853 Semiconductor Electrode System —W. A. Roovers, O. L. Van Steenis. Assignee: North American Philips Company Inc. A device in which a semiconductive member is soldered to a metal disc which in turn is soldered to a support, said soldering operation being performed in a manner that provides effective heat removal during the operation.

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2,836,520 Method of Making Junction Transistors—R. L. Longini. Assignee: Westinghouse Electric Corporation. A method for making junction transistors that includes subjecting a doped alloy semiconductor to gradient cooling.

2,836,521 Hook Collector and Method of Producing Same—R. L. Longini. Assignee: Westinghouse Electric Corporation. A "hook" collector in which the width of the hook producing region can be controlled with respect to thickness and conductivity, said width having a possible thickness of such small measure that the current amplification of the device is quite large.

2,836,522 Junction Type Semiconductor Device and Method of its Manufacture—C. W. Mueller. Assignee: R. C. A. A junction semiconductor device made of germanium or silicon, said device having a surface alloyed indium electrode containing 0.5% to 12% aluminum.

2,836,523 Manufacture of Semiconductor Devices—C. S. Fuller. Assignee: Bell

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

elephone Laboratories. A method of orming an *n-p-n-p* germanium body by iffusing copper throughout an *n*-type afer in order to convert it to *p*-type, eositing on different surface portions, ayers of indium doped lead and anti-iny doped gold, and subjecting the ody to heat so as to form the *n-p-n-p* ructure.

386,524 Method and Apparatus for the roduction of Single Crystals—S. S. Bren-er., C. R. Morelock. Assignee: General lectric Company. A method of making igh strength rod-like single crystals of ungsten by treating alkali metal tung-ates or alkaline earth tungstates in a eated hydrogen atmosphere.

386,713 Transistor Radio Receiver Tuning ndicator—T. M. Scott, L. A. Freedman. ssignee: R.C.A. Means for illuminating he tuning dial of a transistorized receiver vith a minimum amount of power drain.

836,714 Electronic Limiter Circuit— D. R. ndrews. Assignee: R.C.A. A simple ircuit for eliminating phase shift of ulse signals due to variations in ampli-ude or slope of these signals.

836,724 Self-Quenching Oscillator— P. Kaminow. Assignee: Bell Telephone aboratories. A common base transistor olpitts oscillator with a choke and a apacitor connected in series between the mitter and the base is used to produce scillations that are periodically quenched hereby producing a distinctive tone.

836,734 Voltage Control Apparatus— H. Cichanowicz. Assignee: Westinghouse lectric Corporation. A high speed voltage r signal sampling device having off-set oltage points in the order of a millivolt r less.

836,784 Power Supply—T. A. Gross. ssignee: Raytheon Manufacturing Com-any. A power supply system in which oltage variations due to temperature hanges are compensated for by placing resistor, having positive temperature oefficient of resistance, between the *a-c* ource and the input terminals of the elenium rectifier.

836,797 Multi Electrode Field Controlled Germanium Devices—V. Ozarow. As-ignee: General Electric Company. A usion-produced, field-controlled semicon-uctor device which exhibits sharp varia-ions in carrier-type density on opposite ides of the junction, the densities being uch that an exhaustion layer can be stablished on one side of the junction.

une 3, 1958

836,878 Electric Devices Employing Semi-onductors—S. C. Shepard. Assignee: nternational Standard Electric Corpora-on. A method for encasing a semiconduc-or device in a mass of a polymerisable ompound.

837,336 Scoring Circuit—F. M. Brown. ssignee: The Reflectone Corporation. A scoring circuit for a target having a et of spaced electrodes which become nomentarily short-circuited by a bullet assing through said target.

837,448 Method of Fabricating Semicon-uctor P-N Junctions—C. D. Thurmond. ssignee: Bell Telephone Laboratories. Germanium or silicon devices containing arge area strain-free *p-n* junctions.

837,471 Method of Locating P-N Junctions In Semiconductive Bodies—J. T. Law, P. S. Meigs. Assignee: Bell Telephone Laboratories. A method of locating and marking *p-n* junctions by selectively staining the *p*-type zone, the staining agent being a colored dye capable of cathodic reduction.

2,837,591 Germanium Anode Cell—J. W. Rhyne, Jr. Assignee: Hamilton Watch Company. An alkaline dry cell comprising a germanium anode, an alkaline electrolyte, and a depolorizer cathode including an electrolytically reducible oxygen yielding compound.

2,837,605 Subscriber-Loop Carrier Telephone Ringing Systems—L. Hochgraf, W. Koenig Jr. Assignee: Bell Telephone Laboratories. A system for transmitting subscriber ringing information over a carrier line at a power level much less than that required to accomplish actual ringing at subscriber station sets.

2,837,618 Semiconductor Alloys—L. W. Gildart. Assignee: (Private). An alloy for use in thermistors, said alloy being composed of the triselenides or trisulfides of antimony and bismuth and about 2% of the same compounds of arsenic.

2,837,652 Solid State Inverters—J. C. Nailen. Assignee: Electronic Specialty Co., An electrical power inverter for converting *d-c* to *a-c*., said inverter utilizing crystal diodes for this purpose.

2,837,660 Composite Radiation Amplifier—R. K. Orthuber, L. R. Ullery, and C. L. Day. Assignee: International Telephone and Telegraph Corporation. A radiation display amplifier of laminated construction which is composed of a dielectric material of intermixed photoconductive and electroluminescent particles.

2,387,661 Radiation Amplifier—R. K. Orthuber, L. R. Ullery, and C. L. Day. Assignee: International Telephone and Telegraph Corporation. In a radiation amplifier a parallel arrangement of the photoconductive and electroluminescent materials intercoupled conductively to connect corresponding elemental areas of each layer together.

2,837,662 Measuring and Control Apparatus —R. J. Ehret. Assignee: Minneapolis-Honeywell Regulator Company. A system in which the voltage across a potentiometer measuring circuit is continuously compared and standardized to the voltage of a standard cell.

2,837,663 Monostable Trigger Circuit—P. F. Waltz. Assignee: General Dynamics Corporation. A monostable trigger circuit which reverts to its stable condition in a relatively short period of time after producing an output pulse.

2,837,703 Composite Rectifier Assembly—E. Lidow. Assignee: International Rectifier Corporation. A composite metal rectifier comprising in series a plurality of rectifying elements one of germanium and the other of selenium, said rectifier being less susceptible to temperature variations as a result of the complementary resistance—temperature characteristics of selenium and germanium.

2,837,704 Junction Transistors—R. Emeis. Assignee: Siemens-Schuckertwerke Aktiengesellschaft. A junction transistor having amplification factor and a small effective base region resistance.

June 10, 1958

2,838,609 Electric Communication System—D. Eklov. Assignee: Svenska Relafabriken AB (Sweden). In a communication system the response of the signal transmitter to the incoming supplied direct current is utilized to accomplish the automatic regulation of the strength of the received signals.

2,838,612 Telephone Subscriber's Instruments—L. C. Pocock. Assignee: International Standard Electric Corporation. A telephone subscribers station comprising a bridge network including a transmitter and a crystal amplifier, a receiver circuit, a line circuit, a balancing network and a pair of resistive impedances forming two arms of said bridge.

2,838,617 Circuit-Arrangement Comprising a Four-Zone Transistor—L. J. Tummers, F. M. Stieltjes. Assignee: North American Philips Company, Inc. In an amplifier the supply voltages are fed to a four-zone transistor with polarity such that the junction between the first and second zones; and the second and third zones is operated in the forward direction and the third and fourth zone is operated in the blocking directions.

2,837,740 Proportional Gate Circuit—R. L. Riddle. Assignee: Haller, Raymond and Brown Inc. A transistorized gating and amplifying circuit.

2,838,434 Semiconductor Signal Translating Device.—R. G. Pohl. Assignee: The Rauland Corporation. A semiconductor wafer is provided with an aperture therethrough, said aperture being positioned to provide a thin portion between the aperture and the sides of the wafer, and two diffused junction layers on opposite sides of the thin section.

2,838,589 Thermocouple Junction—G. Hunrath. Assignee: U.S.A. Dept. of the Army). A thermoelectric generator including a cylindrical ingot of zinc-antimony alloy and a strip of constantan.

2,838,657 Train Speed Control System—C. S. Wilcox. Assignee: General Railway Signal Company. A speed control system for trains, said system being one in which a variable frequency, proportional to the speed of the train, is amplified by a transistor amplifier.

2,838,664 Transistor Counter Circuit— E. Wolfendale. Assignee: North American Philips Company Inc. A digital counter circuit utilizing a plurality of bistable transistor circuit units connected in succession.

2,838,675 Reversible Current Circuit—C. L. Wanlass. Assignee: North American Aviation Inc. A transistorized multivibrator circuit which produces a reversible output to a load.

2,838,680 Transistorized Rate Meter—A. Bender, A de la Lastra. Assignee: Universal Transistor Products Corporation. A radiation counter and meter amplifying system using a small number of components.

2,838,685 Control Apparatus for Synchronizing Sources of Alternating Current—R. W. Stineman. Assignee: Boeing Airplane Company. A system in which two A.C. sources are automatically paralleled, said sources having a given slip frequency difference, the paralleling action taking place at the in-phase condition.

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Semiconductor Reliability Studies	Bell Labs Record Mar 1960	Discussion of various tests that can be set up to check the reliability of transistors and diodes.	M. C. Waltz
Diffused Junction Depletion Layer Calculations	Bell Syst Tech Jl Mar 1960	Depletion layer properties have been calculated as a function of reverse voltage and of diffusion parameters for the gaussian and the complementary error function distribution.	H. Lawrence R. M. Warner, Jr.
Negative Resistance in Semiconductor Devices	Canad Jl Phys Mar 1960	The properties of the *a-c* impedance arising from the interaction of thermal and non-thermal effects are discussed; negative resistance criteria are derived.	R. E. Burgess
Liquid-Solid Interface Shape Observed in Silicon Crystals Grown by the Czochralski Method	Canad Jl Phys Mar 1960	In two crystals the interface was seen to contain a (111) facet. The development of such facets is discussed with reference to current crystal growth theories.	W. D. Edwards
Back-Transient Diode Logic	Comm & Elecncs (AIEE) Mar 1960	Hole storage may serve as the basis for a new type of diode-switching circuit, referred to as back-transient diode logic.	G. Wolff
A Nondestructive Breakdown Phenomenon in Selenium Rectifiers	Comm & Elecncs (AIEE) Mar 1960	It is possible to observe a type of failure in selenium rectifiers, labeled "stabilized breakdown," which is a nondestructive phenomenon involving a thermal "runaway" to a limiting stabilization point.	A. C. English W. H. Tobin
The Effect of Source and Sink Thermal Resistance on Thermoelectric Generator Performance	Comm & Elecncs (AIEE) Mar 1960	The purpose of this paper is to analyze the static performance of a thermoelectric generator which operates between a thermal source and a thermal sink having nonzero thermal resistances.	P. E. Gray
Stable Transistor Wide-Band D-C Amplifier	Comm & Elecncs (AIEE) Mar 1960	Stable *d-c* amplifiers using transistors can be designed and constructed by modifying the basic techniques used in vacuum tube circuits	Burroughs Corp.
An Investigation of the Dynamic Switching Properties of 4-Layer Diodes	Comm & Elecncs (AIEE) Mar 1960	A presentation of experimental data on the variation of breakover potential for various types of applied voltage waveforms.	G. E. McDuffie, Jr. W. L. Chadwell
Fundamental Considerations of Power Dissipation Limits in Some Bistable Transistor Pulse Circuits	Comm & Elecncs (AIEE) Mar 1960	This paper deals mainly with the problems of speed limitations at various power dissipation levels.	R. Raillard
Transistor and Load Dissipations in Class A and Switching Circuits	Elecl Design News Mar 1960	Two nomographs are provided that can be used to obtain a close approximation of these values.	J. A. Wheeler E. S. Currence
A Small High-Speed Transistor and Ferrite Core Memory System	Elecl Engg Mar 1960	The design and operation of a 400-bit memory system for use in a time-division electronic switching system.	W. L. Shafer, Jr. W. N. Toy H. F. Priebe, Jr.
Infrared Fundamentals and Techniques	Elecl Mfg. Mar 1960	Tutorial survey of the field discusses waves and particles, thermal radiation, interaction of radiation with matter, experimental techniques, infrared materials, and components and applications.	L. J. Neuringer
RMS-Sensing Regulator Designed for Reliability	Elecl Mfg. Mar 1960	By designing one total regulator system for less critical sensor requirements rugged thermal elements can be used for error detection.	G. Schohan
Power Dissipation in Class B Power Transistors	Elecnc Design Mar 30 1960	Use of ideal equations in practical Class B transistors-amplifier design; a 10W Class B push-pull amplifier design example is shown.	A. Schumacher
Designing with Phototransistors	Elecnc Design Mar 16 1930	Four quantities are usually of interest: light sensitivity, chopped light frequency response, photo-spectral response, and noise response.	General Transistor Corp.
Designing Temperature Balanced Logic Elements	Elecnc Equip Engg Mar 1960	The design of a one-shot multivibrator capable of operating over a temperature range of 55°C to +85°C is described.	A. B. Chertoff I. M. Shivack
Tunnel Diode Characterization	Elecnc Equip Engg Mar 1960	Starting with the establishment of stability criteria, test circuits and procedures have been developed for completely specifying the parameters of interest.	S. Cohen
Junction Transistor Circuits	Elecnc Tech (Br) Mar 1960	Method of calculating current drift due to changes of junction temperature in a direct-coupled transistor circuit with negative feedback.	J. J. Ward
Recent Progress in Solid State Technology	Electronics Mar 4 1960	Solid-state device developments; tunnel-diode logic circuits and amplifiers generally discussed.	M. M. Perugini N. Lindgren
Transistorized Tuners for Portable Television Electronics	Electronics Mar 18 1960	Micro-alloy diffused-base transistors applied to tuner give 18-19 db power gain at 210 *mc* with 12 db noise factor.	V. Mukai P. V. Simpson
Battery-Operator Transistor Oscilloscope	Electronics Mar 18 1960	Instrument uses 39 transistors and 3 vacuum tubes. Response is from *d-c* to over 5 *mc*. Deflection-blanked CRT and automatic battery charger circuits used.	O. Svehaug J. R. Kobbe
Automated Assembly of Alloy-Junction Transistors	Electronics Mar 25 1960	Description of automatic electro-mechanical assembler.	T. J. Leach
Boosting Function Generator Output with Transistors	Electronics Mar 25 1960	Diode junction generator is reviewed and a comparison is made between it and the transistor function generator.	D. R. Chick
On The Application of the Base charge Concept to the Design of Transistor Switching Circuits	IRE Trans Circ Theory Mar 1960	A new method of measuring the effective decay time of excess minority carriers in the base of junction transistors is described.	R. S. C. Cobbold
Esaki Diode High-Speed Logical Circuits	IRE Trans Elecnc Comp Mar 1960	Logical circuits using Esaki diodes, and which are based on a principle similar to parametron (subharmonic oscillator element) circuits, are described.	E. Goto et al
The Design of Diode-Transistor NOR Circuits	IRE Trans Elecnc Comp Mar 1960	Considerations leading to the adoption of diode-transistor NOR circuitry for a moderately fast data-processing system are outlined.	D. P. Masher

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onsaturating Transistor Circuitry or Nanosecond Pulses	IRE Trans Nuc Science Mar 1960	A system is described for pulse testing of transistors in the 10^{-10} to 10^{-9} sec range.	R. M. Sugarman
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igh-Speed Switching Diodes rom Plastically Deformed ermanium	JL Appd Phys Mar 1959	Diffused diodes, fabricated from plastically deformed germanium, were examined for high-speed switching response.	G. L. Pearson R. P. Riesz
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roposed Microwave Mixer Diode f Improved Conversion fficiency	JL Appd Phys Mar 1960	By using convergent spherically symmetrical flow of minority carriers in a semiconductor it is possible to improve the conversion efficiency of microwave mixer diodes.	L. B. Valdes
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A Study of the State of Silver and Gold Local Levels in Germanium	Sov Phys Sol State Mar 1960	The authors studied the effects of annealing at medium temperatures (T=400° to 600° C) on the state of the local levels of gold and silver in germanium.	K. O. Glinchuk E. G. Miselyuk N. N. Fortunatov
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A New Longitudinal Magnetoconcentration Effect and its Employment in Determining the Ratio of Heavy and Light Hole Densities	Sov Phys Sol State Mar 1960	Results of an investigation into minority carrier distribution in a magnetic field.	S. M. Ryvkin Yu. L. Ivanov
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Concerning the Statistical Theory of Electrical Conductivity of Semiconductors, III	Sov Phys Sol State Mar 1960	The influence of a new effect which takes into account electron transitions from conductivity band to the impurity levels, and its inverse as a result of collisions with phonons is considered.	M. I. Klinger
Investigation of the Symmetry of Electron Energy Zones in $CdIn_2Se_4$-Type Crystals	Sov Phys Sol State Mar 1960	Using group theory, an investigation was conducted of the electron energy spectrum in these semiconductors.	A. I. Gubanov F. M. Gashimzade
Spectral Fluctuations on Complex Physical Systems	Sov Phys Sol State Mar 1960	Solution of the problem of the spectral intensity fluctuation in similar types of systems is given.	O. M. Kalinan
Application of Magnetoconcentration Effect for Semiconductor Surface Investigation	Sov Phys Sol State Mar 1960	The method of measuring the recombination speed from the resistance changes of a semiconductor in a magnetic field was adapted for the investigation of the energetic structure of the germanium surface.	V. P. Zhuze G. E. Pikus O. V. Sorokin
Measurement of Electrical Parameters of a Semiconductor by U-H-F Techniques	Sov Phys Sol State Mar 1960	Applying the operating principle of an absorbing waveguide attenuator, it is possible to measure the electrical parameters of a semiconductor.	I. I. Gashka Yu. K. Pozhela
Relation Characteristics of Semiconductor Photoresistors and Photoelements	Sov Phys Sol State Mar 1960	From the solution of diffusion equations, the time characteristics of the photoconductivity and photodiffusion-e.m.f. are determined by the operational method.	F. A. Gisina
Industrial Prepardness Study for Diffused Semiconductor Devices; Device No. 2	US Govt Res Repts Feb 12 1960 LC $12.30 PB 138801	Feasibility of design and reproducibility of the fabrication procedures has been demonstrated for 50 samples.	B. B. Frusztajer G. A. Ferris H. C. Rudenberg
Transistorized Interphone Microphone Amplifier	US Govt Res Repts Feb 12 1960 LC $30.30 PB 138552	System uses M-33/AIC microphones, H-70/AIC headsets, and listening amplifiers of the AN/AIC-12 (XC-1) intercommunication set.	W. F. Meeker R. M. Carrell
Theory of Noise in a Multidimensional Semiconductor with a P-N Junction	US Govt Res Repts Feb 12 1960 LC $16.80 PB 144046	The noise problem is solved by using Langein Equations and interpreting the distributed sources as random forces.	M. Solow
A Transistor Zero-Crossing Detector	US Govt Res Repts Feb 12 1960 LC $3.30 PB 144108	A transistorized detector is described which generates a pulse whenever the input waveform passes through zero.	J. S. Denelsbeck
Feasibility of Transistorizing Beacon Radio AN/DPN-31	US Govt Res Repts Feb 12 1960 LC $10.80 PB 138557	It was concluded that transistorizing all stages except the transmitter oscillator, modulator, and modulator driver is now feasible.	R. Olsen R. A. Orlando et al

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
ransistorized Power Supplies: A iterature Survey	US Govt Res Repts Feb 12 1960 OTS $0.75 PB 161266	Various transistor circuits of interest in ammunition electronics for converting *d-c* to *a-c*, or *d-c* to *d-c* are reviewed.	F. Allen
xperimental Analysis of Per- rmance of Galvanomagnetic mplifiers	US Govt Res Repts Feb 12 1960 LC $12.30 PB 142934	Expressions for amplifier gain are developed. Gain is shown to be a junction of the *d-c* power dissipated in the semiconductor element.	R. K. Crooks G. J. Falkenbach T. S. Shilliday
pectrally Selective Infared De- ctor Development	US Govt Res Repts Feb 12 1960 LC $7.80 PB 143340	Two detectors have been made, one sensitive at 9.8μ, and the other to intervals above and below 9.8μ.	A. Rudomanski
xcess Noise in Semiconductors	US Govt Res Repts Feb 12 1960 LC $12.30 PB 143463	In a study of 1/f noise in single crystal silicon and germanium it is found that crystalline imperfections reduce the noise level.	Armour Research Foundation
heory of Shallow Acceptor States Silicon and Germanium	US Govt Res Repts Feb 12 1960 LC $21.30 PB 138559	A qualitative discussion is presented of shallow impurity states in Si and Ge with emphasis on the acceptor states.	D. Schecter
udies, Research and Investiga- ons of the Optical Properties of hin Films of Metals, Semicon- uctors, and Dielectries	US Govt Res Repts Feb 12 1960 LC $3.30 PB 143448	No summary.	L. N. Hadley, Jr.
ffect of Heavy Doping on the iffusion of Impurities in Silicon	US Govt Res Repts Feb 12 1960 LC $7.80 PB 143673	The diffusibility of P, Sb, Sn, and In in heavily doped *n*-type, and *p*-type silicon have been measured.	M. F. Millea
n Drift in an N-P Junction	US Govt Res Repts Feb 12 1960 LC $6.30 PB 143361	Use is made of ion drift in an *n-p* junction for investigating diffusion constants, as well as chemical interactions within the host lattice which affect this diffusion.	E. M. Pell
hotoconductivity of Cadmium elluride	US Govt Res Repts Feb 12 1960 LC $15.30 PB 144263	Single crystals of cadmium telluride with an impurity concentration of about 10^{17} cc^{-3} have been prepared.	C. E. McNeilly
dustrial Prepardness Study on ermanium Power Transistors	US Govt Res Repts Mar 18 1960 LC $63.80 PB 138086	Industrial prepardness studies were undertaken to develop a Ge power transistor, and to develop facilities and equipment to mass reproduce this transistor.	V. K. Erickson D. J. Noggle et al
Review of Maser Amplifiers	US Govt Res Repts Mar 18 1960 LC $4.80 PI 144077	The theory of operation of both the gas and solid-state maser is presented, and aspects of its use as a microwave amplifier, such as band width and noise, are discussed.	A. J. Jaske
ransistors, Junction, Diffused ase, R.F. Power Oscillator, No. 1	US Govt Res Repts Mar 18 1960 LC $10.80 PB 144153	Preliminary processes for the fabrication of a 1W, 70 *mc* transistor are described. Transistor structure is discussed and brief summary of design equations given.	S. H. Barnes P. H. Dirnback et al
ransistors, Junction, Diffused- ase, R.F. Power Oscillator, No. 2	US Govt Res Repts Mar 18 1960 LC $7.80 PB 144156	Processes for the fabrication have remained basically the same as in Report No. 1, but improvements in process control and reliability have been stressed.	S. H. Barnes L. Brown et al
dustrial Prepardness Study on licon Microwave Diodes. No. 1	US Govt Res Repts Mar 18 1960 LC $7.80 PB 138098	Tools to fabricate IN26 and IN78 silicon microwave diodes have been designed and built during this quarterly period (7-1 to 9-30, 1957).	W. H. Forster
dustrial Prepardness Study on licon Microwave Diodes. No. 2	US Govt Res Repts Mar 18 1960 LC $6.30 PB 138102	Silicon microwave diodes types IN26 and IN78 produced on a pilot production line (10-1 to 12-31, 1957).	W. H. Forster
dustrial Prepardness Study on licon Microwave Diodes. No. 3	US Govt Res Repts Mar 18 1960 LC $6.30 PB 138103	Types IN26 and IN78 silicon microwave diodes were prepared. (1-1 to 3-31, 1958)	W. H. Forster
ransistorized Four-Channel adio Remote Control Unit	US Govt Res Repts Mar 18 1960 LC $4.80 PB 144070	Description of a radio remote control unit providing two-wire operational control of from one to four transmitters or receivers from a central location.	J. J. Guba W. E. Wilbur
Semiconductor-Diode Para- etric Amplifier at Microwave requencies	US Govt Res Repts Mar 18 1960 LC $12.30 PB 143735	Measurements were made of the microwave characteristics of the type of diode used in the experimental parametric amplifier with emphasis on the measurement of series resistance.	K. L. Katzebue
vestigations of the Applications Negative Resistance Diodes for witching Circuits	US Govt Res Repts Mar 18 1960 LC $9.30 PB 143978	Study and investigation of pulse circuit applications of three-terminal negative resistance devices.	A. W. Carlson
xcess Noise in Semiconductors	US Govt Res Repts Mar 18 1960 LC $7.80 PB 144274	An experimental study of excess noise in semiconductors resulted in the discovery of fluctuations in the Seebeck effect or thermoelectric potential of semiconductors.	Armour Research Foundation
igh Pressure Effects on Impurity evels in Semiconductors	US Govt Res Repts Mar 18 1960 LC $22.80 PB 143852	Effect of high hydrostatic pressure on the impurity levels due to three different impurities in germanium and silicon.	M. G. Holland
eld-Strength Effects in Cadmi- n Sulfide Single Crystals	US Govt Res Repts Mar 18 1960 LC $3.30 PB 144126	Current-voltage-time characteristics using cadmium sulfide single crystals with *d-c* and undirectional pulse voltages at various temperatures.	H. Gildea
he Use of Electroluminescent hosphors in Thermal Imaging	US Govt Res Repts Mar 18 1960 LC $3.30 PB 144129	Phosphors may be mixed with temperature-sensitive dielectric; or deposited as a film on a temperature sensitive dielectric.	P. A. Silberg
icrowave Crystal Deterioration udies	US Govt Res Repts Mar 18 1960 LC $6.30 PB 144155	It has been found that the process of temporary deterioration can be effected by the application of short duration *d-c* pulses to the diodes in the negative direction.	P. P. Lombardini
udy of Semiconductor Materials d Devices	US Govt Res Repts Mar 18 1960 LC $15.30 PB 137774	The annealing behavior was studied in crystals which were grown from quartz crucibles and in samples where dislocations were introduced by plastic bending.	Raytheon Mfg. Co.
ransistorized Circuits for Use in pace-Research Instrumentation	US Govt Res Repts Mar 18 1960 LC $6.30 PB 144196	Circuits include *d-c* current detectors, voltage-controlled oscillators, voltage generators, timers, and *d-c* to *d-c* converters.	W. B. Wrigley D. W. Robertson T. R. Scott, Jr.
nalysis of Power Dissipation in Two-Transistor Flip-Flop	US Govt Res Repts Mar 18 1960 LC $3.30 PB 144227	An expression for the power dissipation in the collector resistors of the flip-flop is derived.	Philip Emile, Jr.
ariable Capacitance Microwave ode	US Govt Res Repts Mar 18 1960 LC $3.30 PB 143977	9600 *mc* impedance measurements are compared with 1000 *mc* measurements; agreement is fairly good.	Microwave Associates, Inc.
esearch and Development of a lid State Paramagnetic Maser	US Govt Res Repts Mar. 18 1960 LC $3.30 PB 143973	Successful masering has been achieved in several slow-wave structures with typical figures of 10 db gross gain over a 60 *mc* bandwidth.	R. W. Roberts

CHARACTERISTICS CHART of NEW TRANSISTORS

MANUFACTURERS

(In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEIE— Associated Electrical Industries Ediswan Div, Enfield, Middlesex, England
AEIL— Associated Electrical Industries Export, Carholme Road, Lincoln, England
BEN— Bendix Corp.
BOG— Bogue Electric Mfg. Co.
CBS— CBS Electronics
CRY— Crystalonics, Inc.
CSF— Compagnie Generale
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
FSC— Fairchild Semiconductors Corp.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HSD— Hoffman Semiconductor Div.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
KOKJ— Kobe Kogyo Corp., Hyogo-ku, Kobe, Japan
LCTF— Labortoire Central de Telecommunications
MIFI— Microfarad (Italy)
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NAC— National Semiconductor Corp.
NTLB— Newmarket Transistors Ltd.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Landsdale Tube Co.
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
RADF— La Radiotechnique, Div. Tubes Electroniques, 1[illegible] Ave., Ledru Rollin, Paris lle, France
RHE— Rheem Semiconductor Corp.
ROSG— Dr. ing. Rudolph Rost, Ubbenstrasse 21, Hannover [illegible] Germany
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SONY— Sony Corp.
SPE— Sperry Rand Corporation
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
TOSJ— Tokyo Shibaura Electric Co., 1 Komukaitoshiba Cho, Kawasaki, Japan
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments Inc.
TIB— Texas Instruments Ltd.
TUN— Tung-Sol Electric, Inc.
UST— U. S. Transistor Corp.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. (See code at end of chart)
				P_c (mw)	DERATING °C/W	V_{cb}	V_{ce}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
PART 1											
2N404A	5	PNPA	Ge	150	.50	40	35	10			SYL
2N414C	5	PNPA	Ge	200	1000	30	16	7.0	h_{fe}:I_e- 1ma	60	IND
2N734	3	NPNMe	Si	500	300	80	60		h_{fe}:I_e-5.0ma		TI,NAC
2N735	3	NPNMe	Si	500	300	80	60		h_{fe}:I_e-5.0ma		TI,NAC
2N736	3	NPNMe	Si	500	300	80	60		h_{fe}:I_e-5.0ma		TI,NAC
2N742	5☑	NPNMe	Si	500	250	60	60		h_{FE}:I_C-100ma	20min	NAS
2N752	3,4☑	NPNMe	Si	600		85	45	200†	h_{fe}:I_c- 1ma	40-120	NAS
2N754	4	D	Si	300		60	60	30	h_{FE}: 5ma	20-80	TRA
2N755	4	D	Si	300		100	80	30	h_{FE}: 5ma	20-80	TRA
2N756	4,5	NPNMe	Si	500	350	45	45	50	h_{fe}: 1ma	12-22	NAS
2N757	4,5	NPNMe	Si	500	350	45	45	50	h_{fe}: 1ma	18-40	NAS
2N758	4,5	NPNMe	Si	500	350	45	45	50	h_{fe}: 1ma	18-90	NAS
2N759	4,5	NPNMe	Si	500	350	45	45	50	h_{fe}: 1ma	36-90	NAS
2N760	4,5	NPNMe	Si	500	350	45	45	50	h_{fe}: 1ma	76-333	NAS
2N761	4,5	NPNMe	Si	500	350	50	30	50	h_{fe}:I_c- 1ma	19min	NAS
2N762	4,5	NPNMe	Si	500	350	50	30	50	h_{fe}:I_c- 1ma	39min	NAS
2N1054	3	D	Si	5000		125	125	15	h_{FE}: 200ma	20-80	TRA
2N1169	5	NPNA	Ge	120		25	18	7.0	h_{FE}:I_C-200ma	40	RCA
2N1170	5	NPNA	Ge	120		40	20	7.0	h_{FE}:I_C-200ma	40	RCA
2N1217	2	NPNG	Ge	65		20	20		h_{fe}:I_c-2.0ma	40min	GE
2N1510	2	NPNG	Ge	75		75	75		h_{fe}:I_c-1.0ma	8min	GE
2N1617	3	D	Si	60W		80	80	15	h_{FE}: 2A	15-75	TRA
2N1618	3	D	Si	60W		100	100	15	h_{FE}: 2A	15-75	TRA
2N1620	3	D	Si	60W		100	100	15	h_{FE}: 2A	15-75	TRA

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. (See code at end of chart)
				P_c (mw)	DERATING °C/W	V_{cb}	V_{ce}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2N1647	3	D	Si	40W		80	80	10	h_{FE}: 1A	12min	TRA
2N1648	3	D	Si	40W		120	120	10	h_{FE}: 1A	12min	TRA
2N1649	3	D	Si	40W		80	80	10	h_{FE}: 1A	20min	TRA
2N1650	3	D	Si	40W		120	120	10	h_{FE}: 1A	20min	TRA
2N1651	3,5☑	PNPAD	Ge	100W	.80	60	60	3.0	h_{FE}:I_C- 25A	20min	BEN
2N1652	3,5☑	PNPAD	Ge	100W	.80	100	100	3.0	h_{FE}:I_C- 25A	20min	BEN
2N1653	3,5☑	PNPAD	Ge	100W	.80	120	120	3.0	h_{FE}:I_C- 25A	20min	BEN
2N1657	2	NPND	Si	55W	3.0	60	60	10	h_{FE}:I_C- 1A	15min	RAY
2N1660	2,5	NPND	Si	85W	2.06	60	60	40†	h_{FE}:I_C- 1A	90	RAY
2N1666	3	PNPA	Ge		1.5		60	.20	h_{FE}: 6.0A	32max	AMP
2N1667	3	PNPA	Ge		1.5		32	.20	h_{FE}: 6.0A	90max	AMP
2N1668	3	PNPA	Ge		1.5		32	.20	h_{FE}: 6.0A	50max	AMP
2N1669	3	PNPA	Ge		1.5		32	.20	h_{FE}: 6.0A	70max	AMP
2N1673	4	PNPD	Ge	80	.75	35		3.0	G_{pe} at 1.5Mc	30db	SYL
2N1872	2,5	PNPA	Ge	125	.40	5.0	5.0		h_{FE}:I_C- 50ma	95	UST
2N1873	2,5	PNPA	Ge	125	.40	5.0	5.0		h_{FE}:I_C- 50ma	95	UST
2SA94	4	PNPD	Ge	80	750	9.0	9.0	45	PG at 1.5Mc	39db	HITJ
2SA128	1	PNPD	Ge	170	290	40	40	15Ø	h_{FE}:I_C-400ma	35	TOSJ
2SA129	1	PNPD	Ge	170	290	40	40	15Ø	h_{FE}:I_C-400ma	70	TOSJ
2SA130	4	PNPD	Ge	80	750	9.0	9.0	60	PG at 12Mc	16db	HITJ
2SA131	4	PNPD	Ge	80	750	9.0	9.0	45			HITJ
2SA132	4	PNPD	Ge	80	750	9.0	9.0	50	PG at 12Mc	24db	HITJ
2SA133	4	PNPD	Ge	80	750	9.0	9.0	40	PG at 46Mc	39db	HITJ
2SA134	4	PNPD	Ge	80	750	20	20	140	PG at 11Mc	24db	HITJ
2SA135	4	PNPD	Ge	80	750	20	20	150	PG at 100Mc	9db	HITJ
2SB155	2	PNPA	Ge	150	400	16	16	1.0	h_{FE}:I_E-1.0ma	35	HITJ
2SA208	5	PNPA	Ge	120	350	20	15	5.0	h_{FE}:I_C-.20A	40	HITJ
2SA209	5	PNPA	Ge	120	350	20	15	7.0	h_{FE}:I_C-.20A	50	HITJ
2SA210	5	PNPA	Ge	120	350	20	15	12	h_{FE}:I_C-.20A	60	HITJ
2SA211	5	PNPA	Ge	120	350	18	12	8.0	h_{FE}:I_C-.10A	50	HITJ
2SA212	5	PNPA	Ge	120	350	25	12	10	h_{FE}:I_C-.10A	50	HITJ
2SA217	5	PNPA	Ge	120	350	25	12	17	h_{FE}:I_C-.10A	50	HITJ
2SB147	3	PNPA	Ge	12W		60		7Kc△	h_{FE}:I_C-200ma	60	SONY
2SB156	2	PNPA	Ge	150	400	16	16	1.0	h_{FE}:I_E-150ma	60	HITJ
2SB183	1	PNPA	Ge	50	1200	12	9.0	1.0	h_{FE}:I_E-.25ma	55	HITJ
2SB184	1	PNPA	Ge	50	1200	12	9.0	1.0	h_{FE}:I_E-5.0ma	100	HITJ
2SB201	1	PNPA	Ge	160	310	35	35		h_{FE}:I_E-150ma	150	TOSJ
2SB202	2	PNPA	Ge	250	200	32	32		h_{FE}:I_C-150ma	140	TOSJ
2SC11	1	NPNA	Ge	55	900	18	18	3.5	h_{FE}:I_C- 24ma	44	TOSJ
2SC41	3,4	NPNO	Si	50W		150		20	h_{FE}:I_C-1.0A	28	SONY
2SC42	3,4	NPNO	Si	50W		150		20	h_{FE}:I_C-1.0A	28	SONY
2SC43	3,4	NPNO	Si	50W		100		20	h_{FE}:I_C-1.0A	28	SONY
2SC44	3,4	NPNO	Si	50W		50		20	h_{FE}:I_C-1.0A	28	SONY
2SC89	5	NPNA	Ge	120	350	25	15	5.0	h_{FE}:I_C-.20A	40	HITJ
2SC90	5	NPNA	Ge	120	350	25	15	7.0	h_{FE}:I_C-.20A	50	HITJ
2SC91	5	NPNA	Ge	120	350	25	12	12	h_{FE}:I_C-.20A	60	HITJ
2SC173	4	NPNG	Ge	30		15		20	h_{fe}:	27	SONY
2SC175	4	NPNG	Ge	30		15		10	P_G: I_E-1.0ma	41db	SONY
2SC176	4	NPNG	Ge	30		15		10	P_G: I_E-1.0ma	37db	SONY
2SC177	4	NPNG	Ge	30		15		10	P_G: I_E-1.0ma	32db	SONY

NOTATIONS

Under Use

- Low power α-f equal to or less than 50 mw
- Medium power α-f 50 mw and equal to or less than 500 mw
- Power 500 mw •
- r-f/i-f
- Switching and Computer
- Low Noise
- 7- Photo
- 8- Mixer
- 9- Local Oscillator
- ☑ - Revised Spec.
- 10- Chopper
- 11- Matched Pair

Under Type

- A- Alloyed
- D- Diffused or Drift
- F- Fused
- G- Grown
- H- Hook Collector
- M- Microalloy
- Me- Mesa
- O - Other
- S - Surface Barrier
- UNI- Unijunction Transistor
- Y - Symmetrical
- ‖ - Tetrode

Under fab

- * Maximum Frequency
- # Figure of Merit
- △ f_e
- Ø Minimum
- F_T Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under Gain Value

Ø - Pulsed

Under Derating

Ø - Infinite heat sink

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of chart
				P_c (mw)	DERATING °C/W	V_{cs}	V_{ce}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2SC178	4,5	NPNO	Ge	30		15		20	h_{fe}:	26	SONY
2SC191	4,5	NPNO	Si	250		60		50	h_{fb}:I_e-1.0ma	.955	SONY
2SC192	4,5	NPNO	Si	250		60		10	h_{fb}:I_e-1.0ma	.955	SONY
2SC193	4,5	NPNO	Si	250		60		30	h_{fb}:I_e-1.0ma	.955	SONY
2SC194	4,5	NPNO	Si	250		60		50	h_{fb}:I_e-1.0ma	.955	SONY
2SC195	4,5	NPNO	Si	250		30		10	h_{fb}:I_e-1.0ma	.955	SONY
2SC196	4,5	NPNO	Si	250		30		30	h_{fb}:I_e-1.0ma	.955	SONY
2SC197	4,5	NPNO	Si	250		30		50	h_{fb}:I_e-1.0ma	.955	SONY
25T1	1	PNP	Ge	30		11		40Ø	h_{FE}:I_E- 3ma	25min	CDLF
25T2	2	NPN	Si	500		30		20	h_{fe}:I_e-1.0ma	50	FTHF
26T1	1	PNP	Ge	30		11		25Ø	h_{FE}:I_E- 3ma	25min	CDLF
26T2	2	NPN	Si	500		60		20	h_{FE}:I_E-5.0ma	50	FTHF
26T2C	3	NPN	Si	2500		60		20	h_{fe}:I_e-100ma	50	FTHF
28T2	2	NPN	Si	500		30		20	h_{fe}:I_e-5.0ma	14	FTHF
29T2	2	NPN	Si	500		60		20	h_{FE}:I_E-5.0ma	14	FTHF
29T2C	3	NPN	Si	2500		60		20	h_{fe}:I_e-100ma	50	FTHF
35T1	2	PNP	Ge	50		20		4.5	h_{FE}:I_E- 50ma		CDLF
36T1	2	PNP	Ge	50		10		6.5	h_{FE}:I_E- 50ma		CDLF
37T1	2	PNP	Ge	50		10		10	h_{FE}:I_E- 50ma		CDLF
44T1	2	PNP	Ge	400		45	12	1.2	h_{FE}:I_C-150ma	54	CDLF
64T1	2	PNP	Ge	150		30		8.0	h_{FE}:I_E- 10ma	80	FTHF
65T1	2	PNP	Ge	150		30		10	h_{FE}:I_E- 10ma	90	FTHF
941T1	2	PNP	Ge	60		24		1.3	h_{FE}:I_C-100ma	73	CDLF
965T1	2	PNP	Ge	60		24		1.5	h_{fe}:I_e- 1ma	110	CDLF
987T1	2	PNP	Ge	60		24		1.0	h_{FE}:I_C-100ma	36	CDLF
988T1	2	PNP	Ge	60		24		1.2	h_{FE}:I_C-100ma	54	CDLF
989T1	2	PNP	Ge	60		24		.80	h_{fe}:I_e- 1ma	24	CDLF
990T1	2	PNP	Ge	60		24		1.0	h_{fe}:I_e- 1ma	36	CDLF
991T1	2	PNP	Ge	60		24		1.2	h_{fe}:I_e- 1ma	54	CDLF
992T1	2	PNP	Ge	60		24		1.5	h_{fe}:I_e- 1ma	75	CDLF
GT44	4,5	PNPA	Ge	100	500	25	25	2.5	h_{fe}:I_e-1.0ma	30	AEIL
GT45	4,5	PNPA	Ge	100	500	25	25	4.0	h_{fe}:I_e-1.0ma	30	AEIL
GT46	4,5	PNPA	Ge	100	500	25	25	6.0	h_{fe}:I_e-1.0ma	60	AEIL
GT47	4,5	PNPA	Ge	100	500	25	25	9.0	h_{fe}:I_e-1.0ma	100	AEIL
THP106	2	NPN	Si	150		30		10	h_{fe}:I_e-1.0ma	25	FTHF

Newly Announced Registered Transistors (Part 1)

C.P.CLARE TRANSISTOR: 2N315A,2N316A,2N317A,2N356,2N356A,2N357,2N357A,2N358,2N358A,2N377,2N377A,2N385,2N385A, 2N388,2N388A,2N395 thru 2N398,2N404,2N413,2N414,2N416,2N417,2N424 thru 2N428,2N438 thru 2N440,2N438A thru 2N440A,2N444A thru 2N447A,2N519A thru 2N522A,2N578 thru 2N582,2N585,2N587,2N597 thru 2N599,2N602 thru 2N604,2N634 thru 2N636,2N643 thru 2N645,2N658 thru 2N662,2N679,2N1000,2N1012,2N1017,2N1018,2N1065,2N1090, 2N1091,2N1302 thru 2N1312,2N1408,2N1450

ELECTRONIC TRANSISTORS: 2N34 thru 2N38,2N34A,2N43,2N43A,2N44,2N44A,2N59,2N59A,2N59B,2N59C,2N60,2N60A,2N60B, 2N60C,2N61,2N61A,2N61B,2N61C,2N63,2N64,2N78,2N94,2N94A,2N103 thru 2N109,2N111 thru 2N114,2N111A,2N112A, 2N123 thru 2N126,2N123A,2N130 thru 2N133,2N130A thru 2N133A,2N135 thru 2N137,2N139,2N140,2N145 thru 2N147,2N164A,2N165 thru 2N169,2N169A,2N170,2N175,2N180 thru 2N194,2N186A,2N187A,2N188A,2N194A,2N206, 2N211,2N212,2N215 thru 2N220,2N222 thru 2N229,2N233,2N233A,2N237,2N238,2N241,2N241A,2N248,2N249,2N252 thru 2N254,2N265,2N269 thru 2N273,2N271A,2N279 thru 2N284,2N284A,2N291 thru 2N293,2N292A,2N302,2N303, 2N306,2N308 thru 2N312,2N315,2N315A,2N316,2N316A,2N317,2N317A,2N319 thru 2N324,2N331,2N356 thru 2N358, 2N356A,2N357A,2N360 thru 2N369,2N377,2N381 thru 2N383,2N385,2N388,2N393 thru 2N397,2N396A,2N402 thru 2N417,2N414A,2N415A,2N422,2N425 thru 2N428,2N438 thru 2N440,2N438A thru 2N440A,2N444 thru 2N450,2N444A thru 2N447A,2N460 thru 2N462,2N464 thru 2N466,2N481 thru 2N486,2N501,2N506 thru 2N508,2N515 thru 2N527, 2N519A thru 2N522A,2N529 thru 2N533,2N535,2N535A,2N535B,2N556 thru 2N559,2N563 thru 2N569,2N576,2N576A, 2N578 thru 2N587,2N591 thru 2N599,2N609 thru 2N617,2N632 thru 2N636,2N647,2N649 thru 2N651,2N653,2N654, 2N658 thru 2N662,2N679,2N680,2N1000,2N1008,2N1008A,2N1008B,2N1010,2N1012,2N1017,2N1038 thru 2N1045, 2N1056 thru 2N1059,2N1065,2N1086,2N1086A,2N1087,2N1090,2N1091,2N1097,2N1098,2N1101,2N1102,2N1107 thru 2N1111,2N1111A,2N1111B,2N1114,2N1115,2N1121,2N1144,2N1145,2N1198,2N1224,2N1226,2N1280 thru 2N1282, 2N1284,2N1302 thru 2N1305,2N1310,2N1311,2N1316 thru 2N1318,2N1343 thru 2N1357,2N1370 thru 2N1377,2N1383, 2N1446 thru 2N1449,2N1451,2N1452

FRENCH THOMSON-HOUSTON SEMI.: 2N173,2N174,2N174A,2N277,2N319 thru 2N324,2N337,2N338,2N388,2N395,2N396, 2N397,2N508,2N524 thru 2N527,2N1056,2N1057,3N36,3N37

NATIONAL SEMI.: 2N717,2N718,2N720,2N1564,2N1565,2N1566

RAYTHEON: 2N389,2N424

SPERRY SEMI.: 2N698,2N702,2N703,2N715,2N716

SYLVANIA: 2N395,2N396,2N425,2N426,2N427,2N464 thru 2N467,2N484,2N602,2N603,2N604,2N650,2N651,2N652,2N711; 2N1008,2N1192,2N1226

U.S.TRANSISTOR: 2N34,2N43A,2N44,2N45,2N315A,2N316A,2N317A,2N320,2N321,2N323,2N331,2N381,2N382,2N383,2N394, 2N395,2N396,2N396A,2N397,2N696,2N697,2N699,2N1017,2N1348 thru 2N1352

WESTERN TRANSISTOR: 2N327A,2N328A,2N329A,2N1228,2N1229,2N1230,2N1231,2N1232,2N1233,2N1234

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P_c (mw)	DERATING °C/W	V_{cb}	V_{ce}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	

PART 2

2N1670	2	PNPD	Ge	150	500	100			h_{fe}:I_c- 10ma	15min	GTC
2N1672	2,5	NPNA	Ge	150	500	40			h_{fe}:I_c-1.0ma	50	GTC
2N1678	2,5	PNPD	Ge	150	500	60			h_{fe}:I_c-1.0ma	25	GTC
2SA30	1,4	PNPA	Ge	35		12		10	h_{fe}:I_c-.60ma	75	KOKJ
2SA31	1,4	PNPA	Ge	35		12		5.0	h_{fe}:I_c-1.0ma	50	KOKJ
2SA35	1,4	PNPA	Ge	35		16		10	h_{fe}:I_c-.60ma	75	KOKJ
2SA36	1,4	PNPA	Ge	35		16		5.0	h_{fe}:I_c-1.0ma	50	KOKJ
2SA37	4	PNPA	Ge	25	2000	18		7.5	h_{fe}:I_e-1.0ma	65	TOSJ
2SA38	4	PNPA	Ge	25	2000	18		10	h_{fe}: 455Kc	18	TOSJ
2SA39	4	PNPA	Ge	25	2000	18		5.5	h_{fe}: 455Kc	9.0	TOSJ
2SA40	1,5	PNPA	Ge	35		25		5.0	h_{fe}:I_c-1.0ma	65	KOKJ
2SA43	1,4	PNPD	Ge	35		35		30	h_{fe}:I_c-1.0ma	60	KOKJ
2SA64	1,5	PNPA	Ge	30		16		15	h_{fe}:I_c-1.0ma	65	KOKJ
2SA65	5	PNPA	Ge	150	330	18		6.0	h_{FE}:I_C-100ma	70	TOSJ
2SA66	5	PNPA	Ge	150	330	18		10	h_{FE}:I_C-100ma	70	TOSJ
2SA67	5	PNPA	Ge	150	330	18		14	h_{FE}:I_C-100ma	70	TOSJ
2SA72	4	PNPD	Ge	55	900	18		40	h_{fe}:I_e-1.0ma	50	TOSJ
2SA73	4	PNPD	Ge	55	900	18		35	h_{fe}:I_e-1.0ma	50	TOSJ
2SA74	4	PNPD	Ge	125	400	50		70	h_{fe}:I_e-1.0ma	65	TOSJ
2SA75	4	PNPD	Ge	125	400	20		30	h_{fe}:I_e-1.0ma	65	TOSJ
2SA76	4	PNPD	Ge	55	900	18		130	h_{fe}:I_e-1.0ma	65	TOSJ
2SA77	4	PNPD	Ge	55	900	18		110	h_{fe}:I_e-1.0ma	65	TOSJ
2SA78	5	PNPD	Ge	125	400	40		25	h_{fe}:I_e-1.0ma	65	TOSJ
2SA105	1	PNPD	Ge	35		6.0		75	h_{fe}:I_c-1.0ma	50	KOKJ
2SA106	1	PNPD	Ge	35		6.0		30	h_{fe}:I_c-1.0ma	50	KOKJ
2SA107	1,4	PNPD	Ge	35		6.0		20	h_{fe}:I_c-1.0ma	40	KOKJ
2SA108	1,4	PNPD	Ge	35		20		45	h_{fe}:I_c-1.0ma	70	KOKJ
2SA109	1,4	PNPD	Ge	35		20		30	h_{fe}:I_c-1.0ma	60	KOKJ
2SA110	1,4	PNPD	Ge	35		20		30	h_{fe}:I_c-1.0ma	60	KOKJ
2SA111	1,4	PNPD	Ge	35		20		20	h_{fe}:I_c-1.0ma	40	KOKJ
2SA112	1,4	PNPD	Ge	35		20		20	h_{fe}:I_c-1.0ma	45	KOKJ
2SA113	2	PNPD	Ge	50		34			h_{fe}:I_c-1.0ma	45	KOKJ
2SA114	2,4	PNPD	Ge	50		34			h_{fe}:I_c-1.0ma	40	KOKJ
2SA115	2,4	PNPD	Ge	50		34			h_{fe}:I_c-1.0ma	60	KOKJ
2SA116	2,4	PNPD	Ge	50		30		120	h_{fe}:I_c-1.5ma	60	KOKJ
2SA117	2,4	PNPD	Ge	50		30		110	h_{fe}:I_c-1.5ma	40	KOKJ
2SA118	2,4	PNPD	Ge	50		30		100	h_{fe}:I_c-1.5ma	60	KOKJ
2SA136	1	PNPA	Ge	35		6.0		10	h_{fe}:I_c-1.0ma	75	KOKJ
2SA137	1,4	PNPA	Ge	35		6.0		5.0	h_{fe}:I_c-1.0ma	50	KOKJ
2SB32	2	PNPA	Ge	50			20		h_{fe}:I_c-1.0ma	40	KOKJ
2SB33	2	PNPA	Ge	50		20			h_{FE}:I_C- 50ma	70	KOKJ
2SB34	2	PNPA	Ge	150		20			h_{FE}:I_C-150ma	70	KOKJ
2SB37	2	PNPA	Ge	50		35			h_{FE}:I_C- 50ma	70	KOKJ
2SB38	2	PNPA	Ge	150		25			h_{FE}:I_C-150ma	70	KOKJ
2SB39	1	PNPA	Ge	20			10	.85	h_{fe}:I_c-.50ma	45	KOKJ

NOTATIONS

Under Use

1- Low power a-f equal to or less than 50 mw
2- Medium power a-f 50 mw and equal to or less than 500 mw
3- Power 500 mw
4- r-f/i-f
5- Switching and Computer
6- Low Noise
7- Photo
8- Mixer
9- Local Oscillator
☑ - Revised Spec.
10- Chopper
11- Matched Pair

Under Type

A- Alloyed
D- Diffused or Drift
F- Fused
G- Grown
H- Hook Collector
M- Microalloy
Me- Mesa
O - Other
S - Surface Barrier
UNI- Unijunction Transistor
Y - Symmetrical
1 - Tetrode

Under Gain Value

Ø - Pulsed

Under fab

* Maximum Frequency
f Figure of Merit
△ f_e
Ø Minimum
F_T Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under Derating

Ø - Infinite heat sink

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P_c (mw)	DERATING °C/W	V_{cs}	V_{ce}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2SB41	3	PNPA	Ge	8000	1.5	40			h_{fe}:	63	KOKJ
2SB42	3	PNPA	Ge	8000	1.5	60			h_{fe}:	63	KOKJ
2SB61	2	PNPA	Ge	100		30		1.0	h_{fe}:I_c-1.0ma	50	KOKJ
2SB62	3	PNPA	Ge	4000Ø	19	60	60	.40	h_{FE}:I_C-500ma	60	TOSJ
2SB63	3	PNPA	Ge	4000Ø	19	32	32	.40	h_{FE}:I_C-500ma	60	TOSJ
2SB65	2,5	PNPA	Ge	50		30		1.0	h_{fe}:I_c-1.0ma	65	KOKJ
2SB90	1	PNPA	Ge	40	1900	18		1.0	h_{fe}:I_e-1.0ma	65	TOSJ
2SB91	1	PNPA	Ge	40	1900	18		1.0	h_{FE}:I_C- 30ma	70	TOSJ
2SB120	2	PNPA	Ge	50		32			h_{fe}:I_c-2.0ma	70	KOKJ
2SB121	2,5	PNPA	Ge	50		105			h_{FE}:I_C-5.0ma	60	KOKJ
2SB122	5	PNPA	Ge	20WØ	2.5	80	80	.25	h_{FE}:I_C-1.0A	60	TOSJ
2SB124	5	PNPA	Ge	40WØ	1.2	60	60	.30	h_{FE}:I_C- 15A	70	TOSJ
2SB125	5	PNPA	Ge	40WØ	1.2	36	36	.30	h_{FE}:I_C- 15A	70	TOSJ
2SB131	3	PNPA	Ge	11W	1.0	40			h_{fe}:	63	KOKJ
2SB132	3	PNPA	Ge	11W	1.0	60			h_{fe}:	63	KOKJ
2SB149	5	PNPA	Ge	25WØ	2.0	40	20	.25	h_{FE}:I_C-5.0A	60	TOSJ
2SB151	1,5	PNPA	Ge	30W		80	50	4.5KcΔ	h_{FE}:I_C-1.0A	75	KOKJ
2SB152	1,5	PNPA	Ge	30W		100	65	4.5KcΔ	h_{FE}:I_C-1.0A	75	KOKJ
2SB168	2	PNPA	Ge	50		9.0			h_{fe}:I_c-1.0ma	60	KOKJ
2SB169	2	PNPA	Ge	50		9.0			h_{FE}:I_E- 50ma	80	KOKJ
2SB180	3	PNPA	Ge	4000		40			h_{FE}:I_C-500ma	70	KOKJ
2SB181	3	PNPA	Ge	4000		60			h_{FE}:I_C-500ma	70	KOKJ
2SB199	2	PNPA	Ge	150		12			h_{FE}:I_E-150ma	80	KOKJ
2SB200	2	PNPA	Ge	230	110	32			h_{FE}:I_C-150ma	75	TOSJ
CDT1309	3	PNPA	Ge		1.5	40			PG at 2.0A	30db	CTP

NOTATIONS

Under Use

1- Low power a-f equal to or less than 50 mw
2- Medium power a-f 50 mw and equal to or less than 500 mw
3- Power 500 mw
4- r-f/i-f
5- Switching and Computer
6- Low Noise
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10- Chopper
11- Matched Pair

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Y - Symmetrical
1 - Tetrode

Under fab

* Maximum Frequency
# Figure of Merit
Δ f_e
Ø Minimum
F_T Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under Gain Value

Ø - Pulsed

Under Derating

Ø - Infinite heat sink

Newly Announced Registered Transistors (Part 2)

CBS-ELECTRONICS: 2N101,2N102,2N143,2N144
GENERAL ELECTRIC: 2N337,2N338,2N377,2N1304,2N1306,2N1308
GENERAL TRANS.: 2N1000,2N1025,2N1026
HUGHES: 2N327A,2N328A,2N329A,2N1037
INDUSTRO TRANS.: 2N706,2N1420
NATIONAL SEMI.: 2N332 thru 2N338,2N332A thru 2N336A,2N699,2N706,2N707,2N1024, 2N1025,2N1034 thru 2N1037,2N1221,2N1223,2N1275
LA RADIOTECHNIQUE: OC79
RHEEM SEMI.: 2N698,2N699,2N1252,2N1253,2N1409,2N1410,2N1420,2N1507,2N1613
SILICON TRANS.: 2N1047,2N1048,2N1049,2N1050,2N1483,2N1484,2N1485,2N1486,2N1487, 2N1488,2N1489,2N1490
SPRAGUE: 2N240,2N344,2N345,2N346
SYLVANIA: 2N396A,2N397,2N524,2N525,2N526,2N527,2N643,2N645,2N705,2N710,2N725, 2N1224,2N1225,2N1305,2N1307,2N1309,2N1372,2N1373,2N1374,2N1375,2N1376, 2N1380,2N1381
TEXAS INST.: 2N706,2N1253
TRANSITRON: 2N696,2N697
U.S.TRANSISTOR: 2N481,2N519 thru 2N523,2N650 thru 2N654

New Products

Wideband Ultrasonic Transformer

This new transformer from North Hills Electronics covers a frequency range of 20 kc to 10 megacycles impedance, 75 ohms unbalanced to 600 balanced. The unit will handle 1 watt of power. Type 1210-C transformer is epoxy encapsulated

in an aluminum shield can. It has been designed for low insertion loss and good matching characteristics over wide frequency ranges. Balanced windings feature extremely low unbalanced voltage. Bandwidth ratings are conservative.

Circle 96 on Reader Service Card

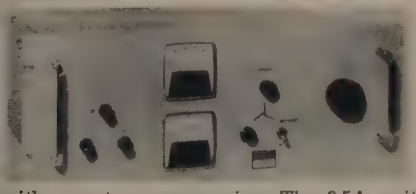
Gallium Arsenide Tunnel Diodes

Philco's gallium arsenide diodes are available with peak currents of 10 and 20 milliamperes. The switching speed figure-of-merit (ratio of peak current to capacitance) is 1 x 10^9 u/sec. The units feature an especially high switching speed when used for millimicrosecond pulse amplifiers. In high speed switching circuits these devices exhibit a signal swing of 1 volt, compared to .25 volts for germanium tunnel diodes, greatly simplifying circuit design. Since shift in bias only slightly affects the new units, more stable high frequency amplifier design is also facilitated.

Circle 102 on Reader Service Card

Transistorized Power Supplies

Trygon Electronics announces the availability of the "60" Silver Series of transistorized, rack mounted power supplies. They furnish a 0-60 Volt variable *d-c* output at 0-2.5 Amps and 0-5 Amps with 0.01% line and lead regulation and less than 1 m.v. ripple. All units are available



with remote programming. The 2.5A unit is programmable over the entire voltage range while the 5A unit is programmable over any 36 Volt range in the 0-60 Volt region. All power transistors have been pre-aged for at least 500 hours in order to optimize their reliability. Electrolytic capacitors are of computer quality thus allowing ambient temperatures up to 60°C and a storage temperature up to 85°C.

Circle 84 on Reader Service Card

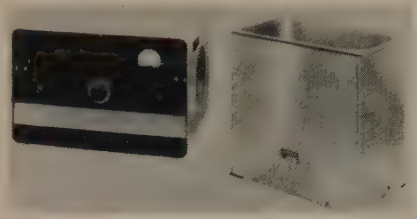
Extended-Range Tunnel Diodes

The Semiconductor Division of Hoffman Electronics Corporation is introducing a new series of silicon tunnel diodes with greatly extended ranges of peak current levels. The line consists of 14 types designated 1N2928 through 1N2934. Peak currents of the new devices range from 470 microamperes to 100 milliamperes. Standard units are available with ±10% peak current tolerance and "A" versions feature ±2% peak current tolerance. The series features excellent uniformity and stability over an operating temperature range of −85°C to +200°C. The units are encased in miniature JEDEC TO-18 packages.

Circle 106 on Reader Service Card

Magnetostrictive Ultrasonic Cleaner

A new ultrasonic cleaning system has been developed by the Harris Transducer Corporation, a subsidiary of General Instruments. Called Sonex, it features a proprietary magnetostrictive transducer, comparable in principle to those developed by Harris for military applications. Because of its strip construction, the new system withstands tank operating temperatures up to 300°F, gives continuous long life operation and is simple to maintain. Only 350 watts of power are required to activate a tank of five gallon



capacity. The system operates at 22 KC for maximum efficiency at minimum noise level.

Circle 78 on Reader Service Card

Component Holders

A newly designed series of spring loaded, component holders, which eliminate the possibility of component lead

shearing, has been introduced by Jupiter Electronics. These component holders are normally used in the labs or in the model shops for early prototype assembly work and for quick set-ups for check-out of semiconductor circuit designs. Machined of brass, these Series II holders employ a stainless steel, type 302 spring for jaw movement and tension and have passed environmental tests to 200°C according to the company.

Circle 87 on Reader Service Card

Alloy Junction Transistors

A series of *p-n-p* germanium alloy junction transistors with a peak power dissipation of 500 mw at 25°C has been made available by Sylvania for medium frequency applications in industrial and military computers. The units (Types 2N395, 2N396, 2N397) have a maximum base to collector voltage of 30 volts, a maximum collector current of 200 ma, and a maximum storage temperature of 100°C. Their 500 mw peak maximum dissipation is defined by a maximum of 50 μs pulse width at a 20% duty cycle.

Circle 94 on Reader Service Card

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Protective Gloves

Charleston Rubber Company has announced their new protective glove "Sensi-Touch" a super sensitive, pliable yet very tough addition to its "Neo-Sol" line. Charco's "Sensi-Touch" protective glove, with satin interior finish, presents a new concept in milled Neoprene gloves, manufactured by the multiple dip cement process. An especially desirable feature is absence of free sulfur or salts, the presence of which, by glove contamination, could cause costly damage when handling fine instruments or parts. The gloves are 10½" long and have a single wall measurement of .007" to .010" for standard, smooth exterior finish and single wall measurement of .010" to .012" for the "Grip-Saf" non-slip hand finish.

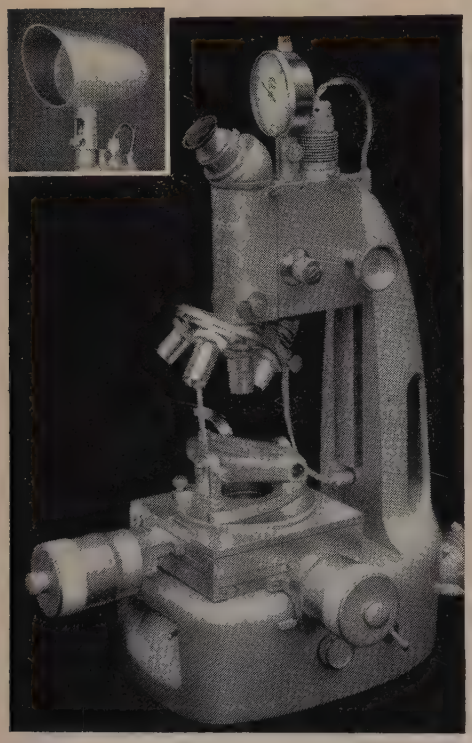
Circle 82 on Reader Service Card

Transistor Checker

Dynatron Laboratories Transistor Checker Model 1003 checks all important transistor d-c parameters, including those in the inverted connection. A remote connector permits checking of parameters while a transistor is in an environmental chamber. The meter's 50 micro-amperes movement enhances the capability to read ICO and IEO. A Beta-Times-Ten scale has been provided permitting accurate indication of Betas up to 1000. A transistor socket accommodates all common transistor case and base configurations. Transistors of unusual case or base styles are easily tested by using the remote connector. The instrument is powered by a mercury cell battery.

Circle 107 on Reader Service Card

MEASURE TO 0.0001" IN 3 DIMENSIONS WITH UNITRON'S TOOLMAKERS MEASURING AND METALLURGICAL MICROSCOPE



The UNITRON Model TM is more than just a measuring microscope. It is the only instrument which combines in one stand a completely equipped toolmakers microscope for precise measurements — LENGTH, WIDTH and DEPTH, and a metallurgical microscope for examining the structure of polished metal samples under high magnification.

NOTE THESE QUALITY OPTICAL & MECHANICAL FEATURES

- **Objectives:** achromatic, coated, 3X, M10X, M40X. **Eyepiece:** coated Ke10X with crosshair.
- **Magnifications:** 30X, 100X, 400X; up to 2000X with accessories.
- **Focusing:** Both dual control rack and pinion coarse and micrometer-screw type fine adjustments. Body has locking device.
- **Three Illuminators:** sub-stage, surface and vertical, have variable intensity.
- **Combination Stage:** rectangular ball bearing with linear measurements to 0.0001" and rotary measurements to 5' with vernier. (Metric model available on special order.)
- **Depth Indicator:** measures in units of 0.0001" by "optical contact" with specimen.
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Circle No. 31 on Reader Service Card

Thermoelectric Probe

A new Thermoelectric Probe, Model TE-1, is announced by Electro Impulse Laboratory, Inc. The probe is suitable

for type testing of semiconductors and metals, detection of *p-n* junctions in semiconductors and the measurement of relative thermoelectric power of semiconductors and all metals. It consists of a sensitive galvanometer, a cold base, a hot point and a variable *d-c* attenuator. The sensitivity is adequate even for metals with low thermoelectric power according to the company.

Circle 81 on Reader Service Card

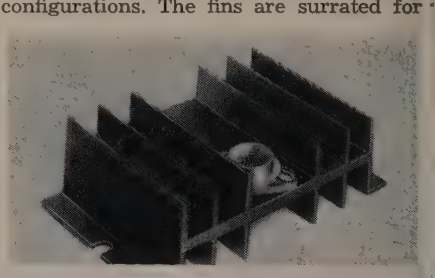
Alloying Furnace

A new Type LAC-55M Series Conveyor Furnace has recently been introduced by C. I. Hayes, Inc., for highly critical alloying of electronic components, metal bonding and soldering, and similar exacting applications calling for extremely close temperature control through the 300°C to 1100° range. Principal design feature is a 3-zone temperature control within the 36" heating chamber to obtain correct temperature curves for the particular work being processed. Controls are available to hold temperatures within ±½°C.

Circle 92 on Reader Service Card

Heat Sinks

Vemaline Products Company 6030 and 6071 natural convection coolers are suitable for most applications. Mixed hole patterns are available; more than one semiconductor can be mounted on same cooler. Hole patterns are available for all standard transistors, diodes and rectifier configurations. The fins are surrated for



maximum surface area in order to obtain utmost performance. Coolers are coined to minimize contact resistance (.05°C 2 Watt). Special coolers are available in longer than 3-1/16" length on request. The 6071 Heat Sink compresses 100 square inches of radiating surface.

Circle 75 on Reader Service Card

(Continued on page 68)

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Model F-20

SPECIFICATIONS:

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• Power Consumption (exclusive of transistor under test)	Less Than 250 Milliwatts
• Self contained collector bias voltage for transistor under test	0-15 volts in 1.5v steps
• Self contained emitter bias current for transistor under test	0-10 ma in 1 ma steps
• Size	14″ W x 9″ D x 9″ H

FEATURES:

- Direct reading, f_T, in mc/sec
- h_{Fe} by simple calculation
- Polarity PNP, NPN
- Simple, direct, and precise instrument calibration
- Provision for external biasing of transistor under test beyond V_{CB} = 15 v, I_E = 10 ma
- Provision for automatic recording
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- Self contained; battery powered, ready for immediate operation

APPLICATIONS:

- Tests all transistors, silicon or germanium, within frequency range
- Suitable for laboratory testing and evaluation
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- Suitable for determining frequency response variation with bias voltage and current
- Rapid Testing

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Circle No. 32 on Reader Service Card

New Products

(from page 66)

Automatic Pumping Station

A new 4″ high vacuum pumping station that is fully automatic has been developed by Veeco Vacuum Corp. The automatic station, VS-401, achieves pump-down to $5x10^{-6}$ mmHg in less than 35 seconds, blanked port, and ultimate pressures of less than $5x10^{-7}$ mmHg. The complete operating cycle is controlled by two push buttons. A start button initiates the roughing cycle. Upon reaching a predetermined pressure setting, a Veeco Type "TC" controller automatically switches the valves from roughing to high vacuum position.

Circle 86 on Reader Service Card

Orienting Table For Crystal Slicing Machine

A new orienting table for their Semiconductor Slicing Machine has been developed by the Electronic Division of the Fitchburg Engineering Corporation. The table simplifies the orienting of semiconductor crystals prior to slicing, and is accurate to 1′ of arc. It can be installed on machines now in operation, or as optional equipment on new machines. These machines are fully automatic slicing machines, and produce wafers with a thickness from 0.025 to 0.007 ±0.0005″. An automatic back-off mechanism minimizes surface imperfections.

Circle 91 on Reader Service Card

High-Temperature Furnace

Pereny Equipment Company has announced a furnace for either specific applications or for general purpose uses which call for long periods of sustained high temperatures. Pereco Model FGKS-1296 Kanthal Super Element Furnace has a chamber size 12″ wide x 8½″ deep x 6″ high, and is 37″ wide x 40″ deep x 64″ high in overall size. Operating temperatures range is from 500°F to 2900°F. Kanthal Super Molydisilicide Elements are suspended equidistant around the work area. Hearth is pure alumina tile, supported on piers to permit heat circulation.

Circle 85 on Reader Service Card

(Continued on page 70)

Industry News

CONFERENCE CALENDAR

The Following October 1960 Meetings Are Scheduled:

Oct 3- 5 6th National Communications Symposium, Hotel Utica & Utica Municipal Auditorium, Utica, N. Y. Sponsored by PGCS Rome-Utica Section. For Information: B. H. Baldridge, 25 Bolton Rd., New Hartford, N. Y.

Oct 3- 5 PG on Nuclear Science, 7th Annual Meeting, Gatlinburg, Tenn. Sponsored by PGNS. For Information: H. E. Banta, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn.

Oct 9-14 AIEE Fall General Meeting, Chicago, Ill.

Oct 10-12 National Electronics Conference, Hotel Sherman, Chicago, Ill. Sponsored by IRE, AIEE, EIA, SMPTE, et al. For Information: Dr. T. F. Jones, Jr., School of E. E., Purdue University, Lafayette, Ind.

Oct 13-14 Engineering Writing & Speech Symposium, Bismarck Hotel, Chicago, Ill. Sponsored by PGEWS & Chicago Section. For Information: Melvin Whitmer, Admiral Corp., 3800 W. Cortland Street, Chicago, Ill.

Oct 13-15 Optical Society of America, Somerset Hotel, Boston, Mass. Sponsored by AIP.

Oct 16-19 Meeting on Industrial Instruments, Broadmoor Hotel, Colorado Springs, Colo. Sponsored by Scientific Apparatus Makers Assoc.

Oct 17-19 Symposium on Adaptive Control Systems, Garden City Hotel, Garden City, L. I., N. Y. Sponsored by Long Island Section et al. For Information: H. Levenstein, W. L. Maxson Corp., 460 W. 34th Street, NYC.

Oct 27-28 Electron Devices Meeting, Shoreham Hotel, Washington, D. C. Sponsored by PGED. For Information: Dr. H. W. Welch, Motorola, Inc., 8201 E. McDowell Rd., Phoenix, Ariz.

Oct 26-28 Conference on Non-Linear Magnetics & Magnetic Amplifiers, Bellevue-Stratford Hotel, Philadelphia, Pa. Sponsored by AIEE, PGIE, PGEC. For Information: D. Katz, Bell Telephone Labs, Whippany, N. J.

Oct 31- Nov 1- 2 13th Annual Conference on Electrical Techniques in Medicine & Biology, Sheraton Park Hotel, Washington, D. C. Sponsored by PGME, AIEE, ISA. For Information: G. N. Webb, Rm. 547 CSB, Johns Hopkins Hospital, Baltimore 5, Md.

Oct 31- Nov 1- 2 Radio Fall Meeting, Syracuse Hotel, Syracuse, N. Y. Sponsored by IRE, EIA. For information: Virgil M. Graham, EIA Engng. Dept., 11 W. 42nd Street, N. Y., 36, N. Y.

(*Continued on page 71*)

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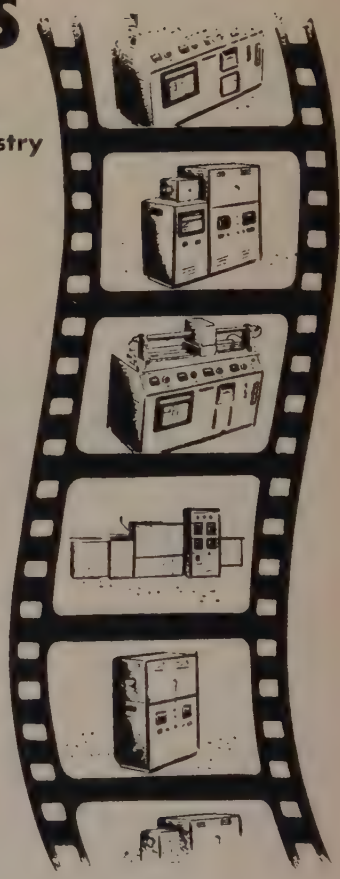

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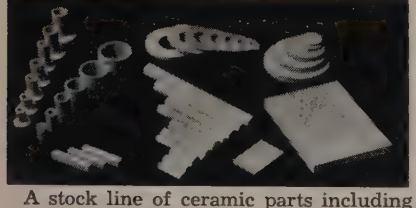
Circle No. 35 on Reader Service Card

New Products

(from page 68)

Ceramic Parts Line



A stock line of ceramic parts including bushings, washers, rods, discs, plates and V-blocks for use at temperatures to 2100°F is now available from Duramic Products, Inc. This new line of stock ceramic components meets the demands of design and production engineers for off-the-shelf components for use in both equipment and tooling. The material used in these components is a high temperature ceramic with excellent thermal shock resistance. The parts can be modified for use in both development and production work by grinding with silicon carbide wheels, or ultrasonic hole drilling.

Circle 101 on Reader Service Card

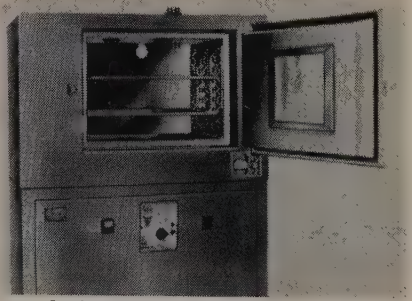
Double Diffused Silicon Rectifiers

Trans-Sil Corp. announced the availability of its new Series 1R Double Diffused Silicon Rectifiers which are capable of operating at ambient temperatures as high as 150°C. The units, solid stack constructed, will deliver up to 2.5 amperes d-c half wave currents, full wave circuits to 12.5 amperes. Peak inverse voltage is in 50 volt multiples. Forward voltage drop and reverse leakage are minimal.

Circle 110 on Reader Service Card

Environmental Cabinets

Blue M Mechanical Convection, Horizontal Airflow Testonic Environmental Cabinets offer an advanced approach to environmental cabinet design. Straight-line control derived from saturable power reactor control system without contacts, switches, moving parts or auxiliary devices, to wear, burn or arc. Consequently, there are no transient voltages due to arcing contacts. Temperature Ranges: 32°F. to 356°F (180°C), 32°F. to 600°F. (316°C) plus constant-flow mechanical refrigeration.



Circle 103 on Reader Service Card

Sample Kits

Tang Industries, Inc. has announced the availability of packaged fill-in assortments of silicon and germanium slices, designed to increase production flexibility and eliminate "short orders" economically. The kit consists of five slices of material in each of the ten most commonly-used resistivity ranges. All slices are .020" in thickness, and measure between ¾" and 1" in diameter.

Circle 83 on Reader Service Card

Oscilloscope

Tektronix type 516 is a dual-trace, semi-ruggedized oscilloscope in the dc-to-15v *d-c* range. It is a compact, easily-portable instrument ideally suited to bench work applications. Basic sensitivity is 50 mv/cm for each channel, with four operating modes possible. Sweep range is adjustable from 0.04 μsec/div to over 6 sec/div. Weighs 45 pounds.

Circle 97 on Reader Service Card

"Plexiglas" Dry Box

Semiconductors, miniature mechanical assemblies, tube components, and other moisture and dust-sensitive items may be handled in rigidly controlled, dust-free atmospheres with the new "Hydrovoid" Atmosphere Control System developed by Air-Shields, Inc. Adaptable to either inert gases or room air, the Hydrovoid contains an efficient desiccant system capable of attaining very low dew points within the cabinet.

Circle 98 on Reader Service Card

Insulating Disc

Mitronics, Inc. announces a subminiature insulating disc with diameters from .020" to .500", in any gradient. Thicknesses range from .008" to .050". This part can be applied to diode assemblies, rectifier insulation, and is ideally suitable for high temperature applications in any type electronic part. This subminiature ceramic part is made from 96% alumina oxide metallized on either or both sides with molybdenum manganese and plated with nickel, copper, gold, etc., depending upon the application.

Circle 108 on Reader Service Card

ndustry News *(from page 69)*

In keeping pace with the accelerated sales efforts of the ndustry, a team of product marketing engineers from the Texas Instruments Incorporated Germanium Products Group convened recently at a product seminar in Los Angeles with representatives of Radio Products Sales, Inc., one of their distributors. The purpose of the evening seminar was to acquaint the personnel of Radio Products Sales with TI's newest products and marketing techniques.

RESEARCH & DEVELOPMENT

Successful development of a high-power, 1,000 megacycle, solid-state power generator, described as a significant advance in telemetry and space communications, was disclosed recently by Pacific Semiconductors, Inc. Dr. Harper Q. North, president of the Thompson Ramo Wooldridge subsidiary, said that the new advance may markedly increase the range of communication in space by eliminating the last of the vacuum tubes in space circuitry, thus prolonging the life of interplanetary transmitters.

The new ultra-high-frequency power generator was made possible through the use of advanced transistors and silicon high-Q voltage-variable capacitors in a combination of optimized oscillator, amplifier, and frequency-multiplier circuits. The UHF generator, Dr. North stated, would be described to the electronic industry for the first time at the annual WESCON show in Los Angeles, Aug. 23 to 26, in a paper written by George Luettgenau, Peter H. Dirnbach, and Murray V. Duffin. The 1-watt power output is reported to be one hundred times greater than the highest power previously achieved at ultra-high frequencies by commercially available semiconductor devices. Dr. North said that the new techniques will also make possible a new high order of reliability in space communications and other applications because the life of a semiconductor device far exceeds that of its vacuum tube counterpart. PSI engineers pointed out that 1 watt of power in the ultra-high-frequency spectrum is entirely adequate for most transmitter requirements.

Solar Cells

The practical "upper limit" in efficiency of solar cells is 15 per cent of the available 130 watts per square inch outside the earth's atmosphere. Present cells are 10 per cent efficient. The limitation was offered by A. B. Francis and W. E. Happ, Lockheed Aircraft Corp., Sunnyvale, Calif., in a paper, "Photovoltaic Solar Energy Converters for Space Vehicles—Present Capabilities and Objectives." It was presented at a space symposium during the Pacific General Meeting of the American Institute of Electrical Engineers.

"Novel fabrication and processing techniques," they said, are constantly improving the efficiency, reliability, and reproducibility of silicon solar cells, and it is optimistically hoped that the theoretical limit of 19.6 per cent, calculated by Loferski, may be approached. Since the efficiency is reduced by contact resistance, surface reflection, and recombination centers, to mention only a few factors, it is estimated that a 15 per cent efficient cell constitutes a practical upper limit." They said that cadmium sulfide "is a particularly promising material" for solar cells "since it exhibits a strong voltaic effect and the mechanism is somewhat different from that of silicon." An increase in the efficiency of photovoltaic cells "may also result from ingenious device designs," they reported.

Large scale production of solar cells "should reduce the price of solar power delivered to below $300 per watt,"

(Continued on page 73)

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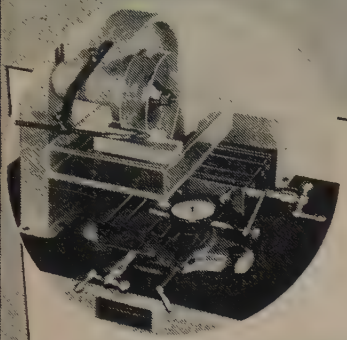
GILLINGS-BRONWILL

THIN SECTIONING MACHINE



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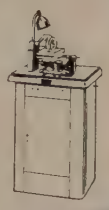

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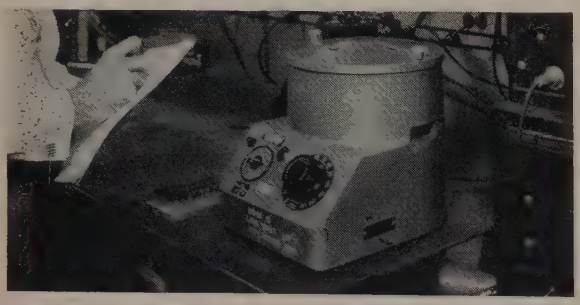
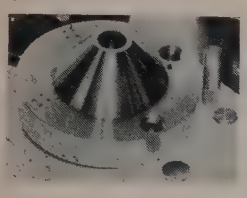
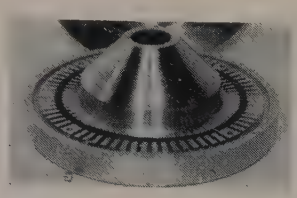


The CSI Centrifuge shown above is used for preforming centrifugal accelerations of 20,000 G tests on transistors and semiconductor products. The rotor shown below on the left has 4 places. Others are available in 6 and 8 places. The rotor shown below on the right has 56 test cavities. Ref.: MIL-T-19500A "Transistors, Gen. Spec. for"





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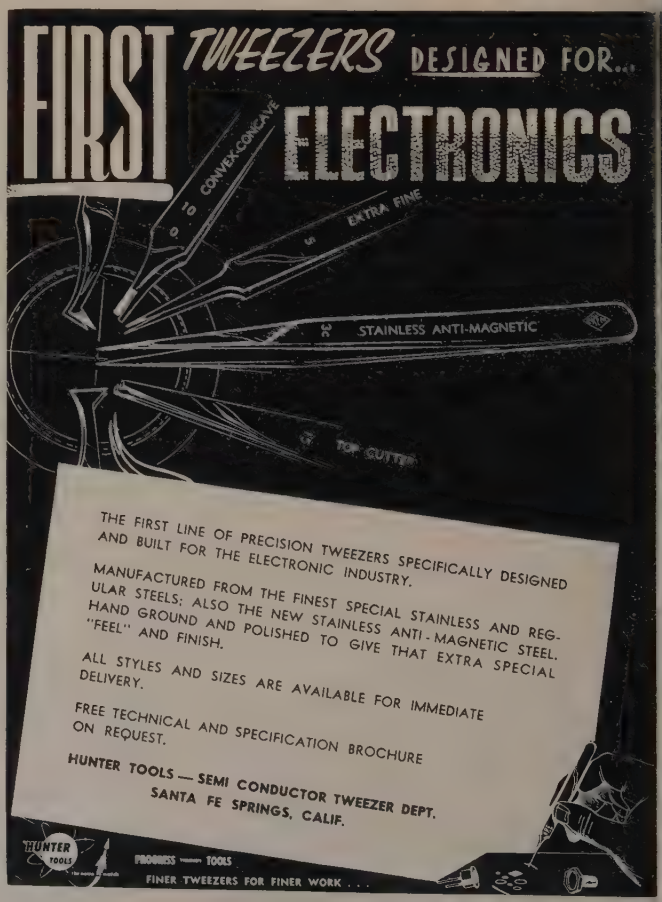

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ney said. "To be competitive with other energy converters ve must look primarily toward improved fabrication nethods resulting in lower cost and higher reliability in ddition to new materials and devices leading to higher onversion efficiencies," they further stated.

The high present cost of solar cells "warrants careful onsideration of panel design to assure the best utilization" onsistent with space vehicle design, the Pacific General Meeting of the American Institute of Electrical Engineers vas told recently. The warning was sounded by S. J. McCunney, of Convair, San Diego, in a paper, "Configura-ion Effects on the Performance of Solar Photovoltaic ystems for Earth Satellites," presented at a symposium n solar power in space. He described a solar photovoltaic ollector as a "device which converts a portion of incident hoton to direct electric potential when the collector is xposed to solar radiation."

"The present design technique," he said, "is to build ollector panels from large quantities of individual boron oated silicon crystal (about 1cm x 2cm x 0.04 cm. ea.) nounted on structural backing." Such cells with 10 per ent efficiency at 30° centigrade, are now available at about 2,000 per square foot. The cost of such cells varies from 700 to $6,000 per watt of average connected load, depend-ng on collector configuration and orientation. "Improved roducibility promises some future price reduction but a arge price reduction can only occur if the present produc-ion rate of 150 sq. feet per month is greatly expanded."

Earth oriented satellites permit better utilization of solar anels than do rotating vehicles, he said.

DESIRED: AN INDUSTRY WITHIN AN INDUSTRY

A major, rapidly expanding electronics corporation desires to establish an independent subsidiary whose activities would encompass one or more of the following areas:
Exotic metals, intermetallic compounds, semiconductor materials and subcomponents, metallized ceramics, and high temperature plastics and ceramic coatings.

For the individual, group of individuals, or small company capable of establishing and operating a successful business in these fields, substantially monetary and long-term growth benefits are offered. A broad, exacting combination of scientific, production, business, and leadership skills are essential.

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Vice-President, Corporate Planning,

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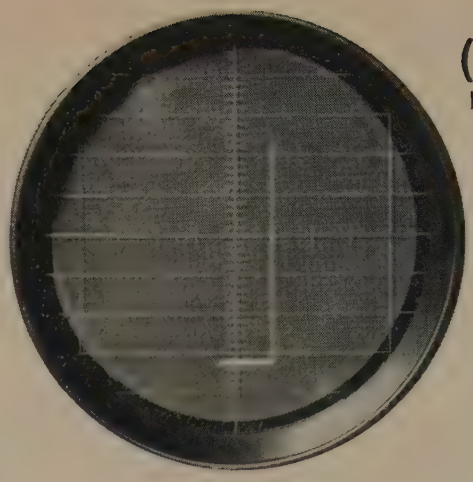
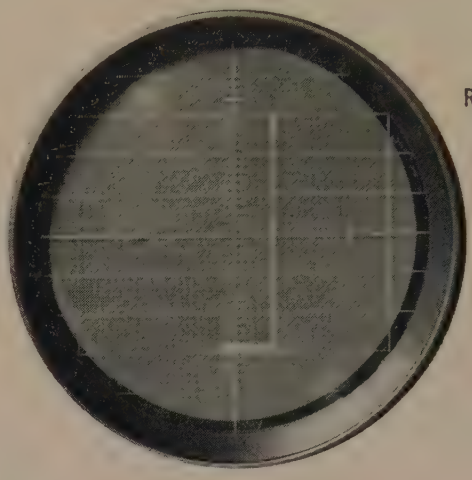


(before)
Reverse leakage tracing before immersion in H_2O_2.



(after)
Reverse leakage tracing after immersion in H_2O_2, dried without washing (virtually no change).

Here's proof !

No increase in reverse leakage when you etch diodes in

BECCO Hydrogen Peroxide!

To test the effect of impurity-free Becco Hydrogen Peroxide across an unsealed diffused silicon junction diode, the following "torture test" was performed: 600 volts AC were applied across the diode, and the reverse leakage current depicted on an oscillograph. Then, the diode was immersed in Becco 30% Reagent Grade Hydrogen Peroxide. The diode, without being washed in any way, was placed on a hot plate and the H_2O_2 was evaporated.

The voltage was re-applied and the tracing produced was virtually identical (see above)—proof that no impurities that could affect the diode exist in Becco Hydrogen Peroxide.

Of course, you'll use Becco H_2O_2 at a different stage—when you etch the diode. And, of course, good practice still dictates that you wash the diode in pure water following the etch. Nevertheless, this test proves that you need not be too concerned with your wash when you etch in Becco H_2O_2, since the peroxide itself, made by an inorganic method, can not deposit any impurities of its own on the diode.

Becco packages its Reagent Grade H_2O_2 in returnable or non-returnable polyethylene containers to insure its purity when it arrives at your plant. Write us for further information or specifications, analysis, prices, etc. Address: Dept. SP-6.

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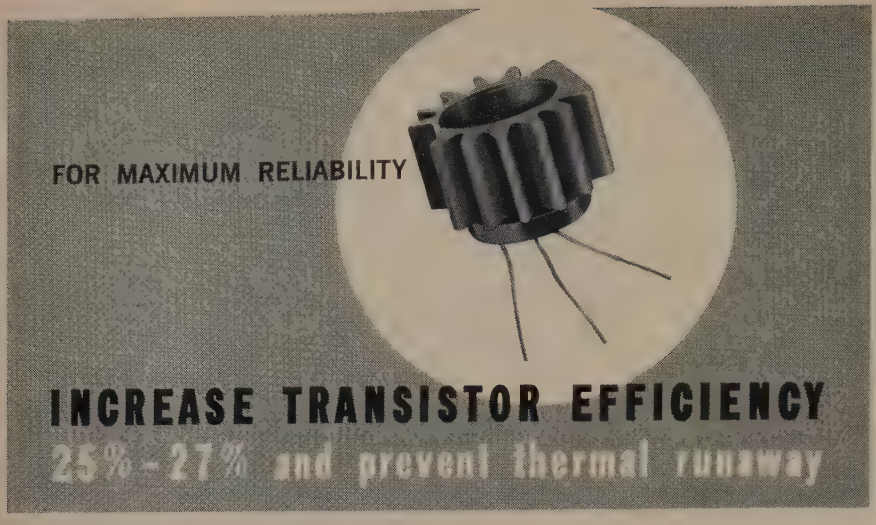

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and thermal runaway is prevented!

To assure circuitry reliability . . . specify Birtcher radiators. Birtcher qualification tests conducted under MIL standards prove these performance results.

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NEW SERVICE NOW AVAILABLE

SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

Market News

Sales

According to the Finance Ministry the export of transistor radios (with three or more transistors) from Japan to the United States was:

April 1960	487,000 units
May 1960	424,000 units

June shipments were very small because of the suspension of export licensing but shipments resumed under quota control in July.

The ministry also reports that approximately 2.4 million transistors were shipped to the U.S. last year. For the first four months of 1960 shipments were 520,80[illegible] units against 114,000 units for the same period in 1959.

EIA has reported that revenue from May factory sales of transistors rose by $947,797 over the total for April, although the number of units sold declined by 844,999. Total units sold during 1960 was up by a comfortable 72 percent over the total for the same period in 1959. Revenue was 53.6 percent ahead. The following tables show EIA's transistor figures for the year and year-to-date totals for 1959:

Factory Sales	*(Units)*	*(Dollars)*
May	9,046,237	$24,146,37[illegible]
April	9,891,236	23,198,57[illegible]
March	12,021,506	28,700,12[illegible]
February	9,527,662	24,831,57[illegible]
January	9,606,630	24,714,58[illegible]
Year-to-date '60	50,093,271	125,591,22[illegible]
Year-to-date '59	29,163,813	81782,18[illegible]

Prices

The Lansdale division of Philco Corp. has developed a germanium backward diode which produces a low forward voltage drop through the utilization of tunneling. These are available at $4 each in prototype quantities. The firm has announced price reductions of 13 to 48% on transistors in their Si surface alloy and their germanium MADT transistors, and has also begun marketing microwave coaxial MADT (micro-alloy diffused-base) transistors in engineering quantities at $125 each.

Hoffman Electronics Corp. has reduced prices by 40% on its HT-1 through HT-10 tunnel diodes. These are now priced at $15 each in 1-99 quantities and at $11.25 each in quantities of 100-999. The firm has also introduced a series of 14 silicon tunnel diodes designated 1N2928 through 1N2934. Standard units are priced from $12.50 to $19 each in quantities less than 100, while the "A" versions are priced from $17.50 to $26.60 each in the same quantity.

General Electric Co. has announced a 93% reduction on its gallium arsenide tunnel diodes

The Semiconductor division of Sylvania Electric Products, Inc. has developed two series of Si mesa diodes measuring as small as ⅛" in length and width. These operate in the kmc region and are priced in sample quantities from $50 to $100 each.

NEW TRAK®
TUNNEL DIODE
CURVE TRACER

$47.50

2" x 3¾" x 6¼"

Used with a laboratory oscilloscope, the TRAK Curve Tracer presents the current-voltage characteristics of tunnel diodes continuously throughout the negative resistance region.

Plug-in adapter serves present tunnel diodes, and others will be made for new packages or electrical characteristics.

One range switch controls vertical deflection signal and another the horizontal sweep voltage from 0 to 1½ volts. Power source: 115v 60 cycle.

ORDER NOW—$47.50

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Distributors

Hollywood Radio Supply, for 15 years one of the foremost industrial electronics distributors in the west, has now changed its name to Hollywood Radio and Electronics, Inc and has moved to new expanded facilities that extend over 25,000 square feet, located at 5250 Hollywood Boulevard, Hollywood 27, California. HRE represents and distributes components of the foremost manufacturers in industrial electronics and services the OEM market with one of the largest inventories of electronic parts and accessories in the west.

Hoffman Electronics has appointed Tekko, Inc. of Dallas as their South Central area distributor for their Semiconductor division. Tekko recently purchased Progress Electronics of the Southwest, former Dallas-based distributor for Hoffman semiconductor products. The company will handle the complete line of Hoffman silicon diodes, Zener diodes, Zener power regulators, transistors, tunnel diodes, and solar cells.

Rheem Semiconductor Corporation has appointed four new distributors. Those appointed are Radio Shack Corporation, Boston; Arrow Electronics Inc., Mineola, New York; Radio Electric Service Co., Baltimore, and Rissi Electronic Supply Co., Detroit. These distributors offer the complete Rheem line of silicon mesa transistors and silicon diodes.

Financial

Hoffman Electronics Corp. has reported sales for the six months period ending June 30 of $23,935,550 as compared with $22,345,189 during the same period in 1959. Earnings per share were 8¢ against 74¢ last year. This drop was attributed to the heavy start-up costs of the firm's new Semiconductor division plant in El Monte, Cal. and their science center in Santa Barbara, Cal.

General Instrument Corp. for the first fiscal quarter ending May 31, 1960 has doubled its profits over the same period in 1959. Net profits were $430,923 equal to 25¢ per share on 1,758,123 shares as compared with $211,129 or 14¢ a share on 1,497,723 shares in May 31, 1959. The gain was especially due to increases in the military and industrial sales, particularly in the semi-conductor field. Semi-conductor shipments in this quarter were about 46% higher than the like period a year earlier.

Raytheon Co., has reported sales in the first half of 1960 of $277,564,000 and net profits of $4,187,000. In the comparable period of last year sales were $235,164,000 and profits $5,112,000. Their backlog of government business at the end of the second quarter was in excess of $330 million.

Fairchild Semiconductor Corp. has acquired a one-third interest in Societa Generale Semiconduttori of Milan, Italy for overseas manufacturing and marketing of their semiconductors.

Wallson Associates, Inc., manufacturer of electronic test equipment, reported for the year that ended April 30, 1960, a record sales increase of 117% over the previous corresponding year. Sales volume rose to $463,573 from $214,332. This was the fifth successive year in which Wallson's sales approximately doubled that of the year before. The company completed a successful public offering in May.

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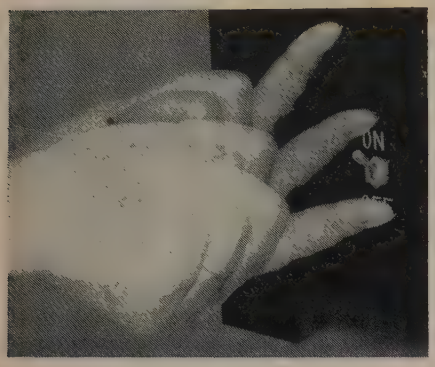


with SELF-TUNING

Self-tuning Autosonic cleaners by Powertron clean faster, better and cheaper because they: Eliminate operator training and monitoring; Release labor for other work; Reduce rejects; Save on solvents.

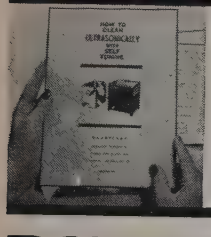
HERE'S HOW IT'S DONE

The Autosonic is electronically self-tuned by its exclusive feedback transducer and requires no tuning knobs or meters. A simple switch is the only control.

Only Autosonic cleaners give you consistent peak performance cleaning regardless of load, solution level or temperature, contamination or operator inattention.

Powertron's complete line of Autosonic generators, tanks, cabinet models, degreasers and immersible transducers is immediately available from stock. Ask for free demonstration by Sales Engineer.

*Case Histories on File.



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DEPT. SP-9
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Directors of Rheem Manufacturing Company have declared a dividend of 15 cents a common share, payable September 9, 1960 to shareholders of record August 10, 1960, and the regular quarterly dividend of $1.12½ a share on the preferred stock, payable September 1, 1960 to shareholders of record August 10, 1960. There are 2,006,809 shares of common stock and 7,815 shares of preferred stock outstanding.

Expansion

Philco Semiconductor division has recently completed construction of a $3.5 million, 84,000 square foot addition to its plant in Lansdale. The firm has also started building a 100,000 square foot addition to the division's facility in Spring City, Pa.

Contracts

Fairchild Semiconductor Corp. has been awarded a $450,258 contract to provide high reliability transistors for the Air Force Minuteman intercontinental ballistic missile program. Autonetics is the prime contractor.

Pacific Semiconductors, Inc., Culver City, Calif., $98,529 for research and development work for 12 months on Intrinsic Silicon Transistor Techniques, Contract #74887.

A split award to Texas Instruments, Inc., Dallas, Tex., $2,625.00 for transistors, item 1; U.S. Semiconductor Prods., Phoenix, Ariz., $494.00 item 2; Motorola, Inc., Phoenix, Ariz., $2,193.75 item 3; International Rectifier Corp., El Segundo, Cal., $1,008.00 item 4. IFB-1066.

A split award to Sprague Electric Co., No. Adams, Mass., $36,320.80 for 1 item of transistors, type 2N393; Philco Corp., Lansdale, Pa., $6,400 for 1 item. IFB-914.

Rheem Semiconductor Corp., Mt. View, Cal., $14,100.00 for 1 item of semiconductor devices, type 1N457. IFB-805.

Hoffman's Semiconductor Division has been selected to fabricate 12 solar energy converter power panels under a $548,000 contract from the California Institute of Technology Jet Propulsion Laboratory, coordinator of the lunar study program for NASA.

General Instr. Corp., Newark, N. J., $6,707.60 for 1 item of semiconductor devices, type 1N1149. IFB-916.

Hughes Products Group, Hughes Aircraft Co., Newport Beach, Cal., $150,000, contract #85065, 18 months investigate study of tunnel diodes.

Texas Instruments, Inc., Dallas, Tex., $42,947.00 for matched pairs of transistors.

Suppliers

Military type silicon mesa transistors (USA) 2N696 and (USA) 2N697 per MIL-S-19500/99A (SigC) are available from Rheem Semiconductor Corporation. Manufacturers can uow use these transistors in equipment for the military without having to obtain "non-standard" part approval. They are immediately available in production quantities on orders referencing military contracts. No increase in price.

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(INSENSITIVE TO GROUNDED CAPACITANCE)
CAPACITANCE BRIDGES

MODEL 74C
- 100 KC Test Frequency
- 0.0002-11,000 μμf Generally 0.25%
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F-2010	.263	.410	.325
AAT-408	.307	.376	.325
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GEN-2020	1 1/16"	1 1/4"	7/8"

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- Without affecting circuit
- No correction factors needed
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- Better than ¼ % accuracy

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Lowest energy drain (to $4x10^{-10}$ watts full scale) and negligible insertion loss mean *fast, accurate, direct* measurements. And only with Greibach Precision Meters . . . the only meters with patented, frictionless BIFILAR SUSPENSION and weightless LIGHT BEAM POINTER. Multiple ranges (to 23) let you handle virtually all measurements *with one meter.*

OTHER EXCLUSIVE GREIBACH ADVANTAGES

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- Sensitivity to 0.2 microamp full scale
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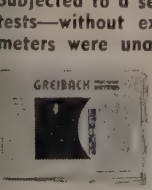
GREIBACH Precision meters can take it! Subjected to a series of transistor punch-thru tests—without external protective circuits—meters were unaffected in any way.



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New Literature

(*from page 26*)

Completely updated October 1960 edition of D.A.T.A.'s SEMICON. DIODE & RECTIFIER CHARACTERISTICS TABULATION soon available with data on all currently manufactured types. New subscription orders received prior to publication of October edition will be entered to include free copy of April 1960 edition containing about 7,000 types. Subscription price $23.25 U.S. & Canada, $25.25 elsewhere. Send orders to Derivation And Tabulation Associates, 95 Harrison Ave., West Orange, N. J.

Circle 176 on Reader Service Card

A two-color, six page folder to aid buyers and engineers in the selection of Westinghouse Silicon Rectifiers and Transistors is now available from Schweber Electronics. The folder, which is fully illustrated, includes details of voltage ratings, capacity, performance, etc. arranged in quick-reference, tabular form. Comprehensive price list also available.

Circle 177 on Reader Service Card

A new 24-page catalog offered by Weldmatic Division Unitex Corporation shows complete line of stored-energy, capacitor-discharge power supplies, precision welding heads and handpieces, and welding accessories. A special section presents advantage of resistance welding, compares stored-energy welding to a-c welding, and outlines important factors in selecting stored-energy equipment. Photos of typical precision-welding applications are included.

Circle 178 on Reader Service Card

Sarkes Tarzian, Inc. has released its new 8-page Selenium Rectifier Catalog No. 4002. The catalog carries cell ratings and detailed specifications and dimensions with maximum and minimum voltage and current ranges of high voltage stacks, power stacks, and a-c and d-c surge suppressors. The booklet covers all types of construction, including open type, embedded and metal enclosed. Also included are stack connections for various types of circuits.

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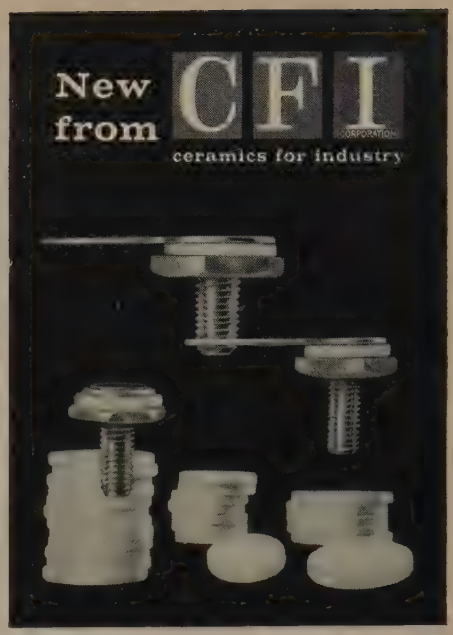

High Alumina Ceramic Diode Base Assemblies

New CFI Series 696 ceramic built into diode base assemblies—another production breakthrough from CFI's fully integrated ceramic service to industry.

The 696 Series features 97 per cent minimum Alumina content, a basically finer grain structure for improved thermal conductivity in diode base assemblies and higher tensile strength that gives strip test values consistently 50 per cent greater than product specifications call for.

These diode base assemblies are available from CFI in the 696 Body in production quantities or as sample lots for engineering and quality evaluation. **Use coupon below for free CFI data.**

Tunnel Diode Envelopes

CFI is currently making ceramic tunnel diode envelope composites for manufacturers on a company classified basis. We would be glad to work on your tunnel diode specifications and requirements with your engineers.

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☐ Semiconductor Ceramics Spec Sheet
☐ Have technical representative contact me.

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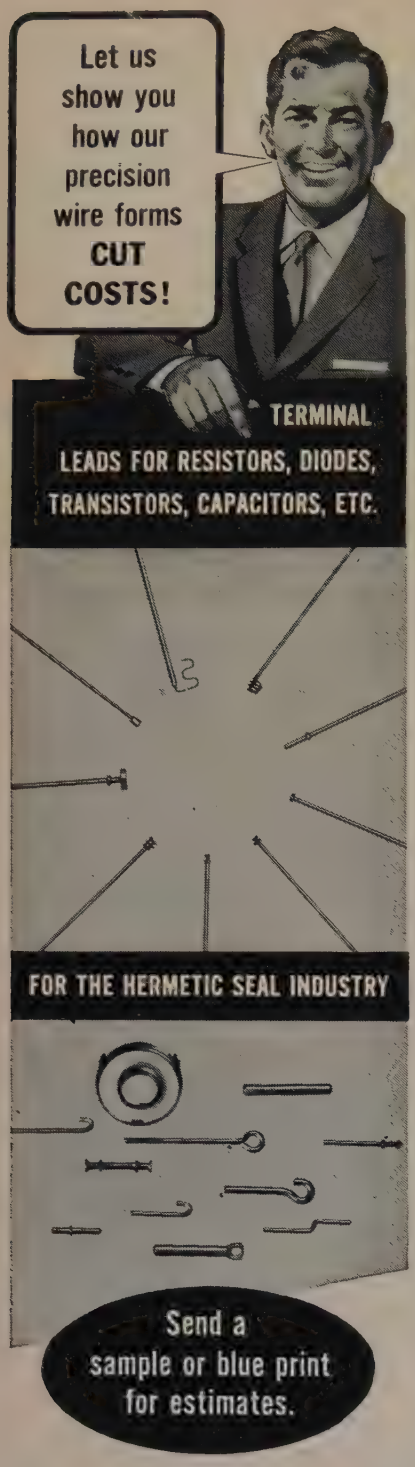
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TERMINAL LEADS FOR RESISTORS, DIODES, TRANSISTORS, CAPACITORS, ETC.
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When Art Wire tackles the job, big gains in precision and uniformity are possible on small components . . . resulting in big savings in time and production costs. In addition, Art Wire's modern production methods produce a wide variety of components more economically.

Art Wire specializes in wire forms designed for today's automatic production lines . . . manufactured to assure the economy of an uninterrupted work flow.

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Ultrasonic Cleaning Technology

A new method of ultrasonic cleaning, was demonstrated recently by Powertron Ultrasonics Corporation. Optimum cleaning performance has been achieved through the use of an integral feedback transducer, which automatically adjusts phase and frequency for all conditions. 3000 hour tests and trials in many industrial applications have proved the durability and reliability of the equipment.

The feedback transducer measures the amount of ultrasonic activity—ultrasound waves—in the cleaning tank, and corrects output phase and frequency to maintain the standing wave condition. Consequently, maximum cavitation—the "cold boiling" on which all ultrasonic cleaning is based—is maintained automatically for all conditions. Thus, heating or cooling, change of solvent, variation of product or material to be cleaned, or other changed conditions have no effect on the efficiency of the autosonic system.

Ultrasonics has been universally adopted by government, commercial and industrial users for cleaning everything from printed circuits to missile parts, to watt-hour meters. This cleaning is accomplished by introducing intense sound waves above the audible limit (28 kilocycles) into a tank containing the cleaning solution and the parts to be cleaned. The intense ultrasound creates the formation and rupture of millions of voids (bubbles thousands of times a second.) The implosion of these voids creates enormous forces (30,000 to 50,000 psi) in the locale of the part to be cleaned. This Cold Boiling, or scrubbing known as CAVITATION, literally pulls foreign particles from the surfaces and most intricate recesses of the parts to be cleaned.

Cleaning systems ranging in capacity from 100 to 3,000 watts are being produced by Powertron, all with the self tuning feature. Among them are generator-tank combinations in a variety of sizes from ¾ gallon to 75 gallons.

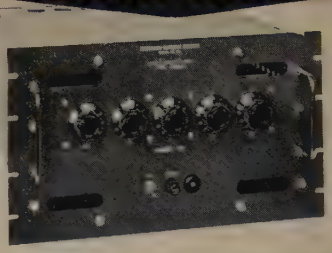
APPLICATIONS

(From page 53)

R_B and R_L. The value of C may range from 0.1 to 10 μf depending upon the values of R_L, R_B, the device under test, and the value of E_{bb}.

To operate the circuit, connect it as shown, keeping all leads as short as possible. Closing *SW1* will cause the controlled rectifier to fire. The reverse recovery current may be observed when the relay is closed, causing the circuit to commutate. Peak recovery current can be adjusted with R_B and forward anode current can be adjusted with R_L. To observe the rate of rise of reapplied forward voltage, connect the oscilloscope to terminal "A." Changing C will give the desired rate of rise. R_B should be readjusted as before. ■

NORTH HILLS



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▸ High Accuracy ▸ Excellent Stability ▸ Programmable

For testing and measurement of transistors, diodes, clutches, solenoids, meters, other current sensitive devices.

- Current Range is 10μa to 500 ma with 5 decade selectors.
- Regulation and stability 0.05%
- Accuracy 1%

In use by leading companies for transistor avalanche test, diode PIV test, clutch testing, calibration.

Literature describing this and other constant current sources from 0.1μa to 30 amp. may be obtained from

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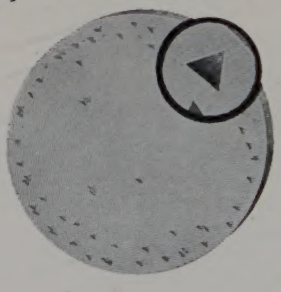

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